Life Cycle Assessment of
UBC Biological Sciences Complex Renew Project

Prepared for:

UBC Project Services

by:

Athena Sustainable Materials Institute

in association with:

Recollective Consulting

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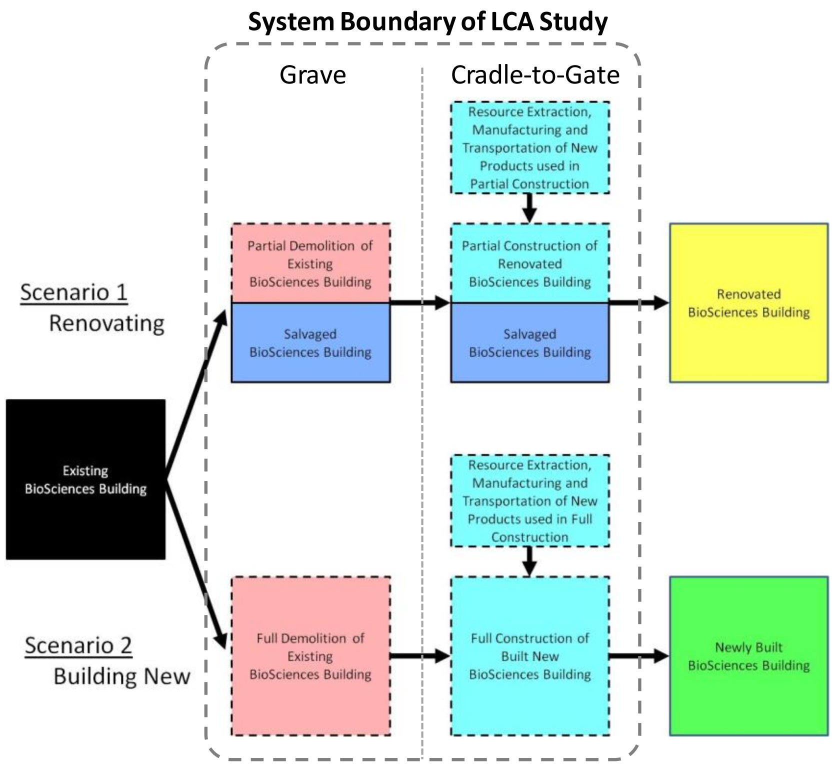

Title	**Life Cycle Assessment of UBC Biological Sciences Complex Renew Project**
Study Commissioned by	UBC Project Services 2329 West Mall, Room 1100 Vancouver, BC V6T 1Z4
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About the Athena Institute:

The Athena Sustainable Materials Institute is a not for profit research institute dedicated to fostering sustainable development in the built environment. Athena uses life cycle thinking, applying life cycle management tools and sustainability metrics to help its members and clients benchmark the environmental performance of their facilities and operations and identify areas for improvement. Renowned for its internationally acclaimed life cycle inventory databases and life cycle assessment software and tools, Athena is credited with putting the application of LCA to the built environment on the map with its development of the Impact Estimator (IE) – the only North American software tool that evaluates the life cycle embodied effects of whole buildings and assemblies.

Executive Summary

The Biological Science Complex (BioSciences building) recently underwent a renovation as part of the Renew Project, a University of British Columbia (UBC) programme to upgrade aging buildings at the UBC Vancouver campus. This report summarizes a life cycle assessment (LCA) study competed at the request of UBC Project Services to transparently communicate the environmental benefits of their decision to upgrade the existing BioSciences building by renovating rather than demolishing and building new. Secondly, this report is an asset in furthering the development of LCA into sustainability in building construction practices at UBC as LCA is rapidly gaining acceptance at all scales of sustainable construction standards and corporate social responsibility policies.

The BioSciences LCA study involved the development of two scenarios, one to describe the actual BioSciences building, where the existing building is renovated, and a hypothetical scenario, where the existing building was demolished and a new building was constructed in its footprint. These Renovated and Building New scenarios were then compared in order to determine LCA results to describe their relative environmental merits. Two strategies are embodied in this report in order to satisfy the intended applications the BioSciences LCA study. Firstly, the Goal & Scope Document provides concise descriptions for each parameter of this LCA study in accordance with ISO 14040 and 14044. Secondly, the models and their results can be completely reproduced in the Impact Estimator using Input and Inputs Assumptions Documents included in the Appendices of this report.

The most notable avoided inventory analysis results from the comparison of the Renovating and Building New scenarios are avoiding the consumption of approximately 4 million L of water, 16 tonnes of coal, 280,000m^3 of natural gas and 120,000 L of crude oil. The results of comparing Renovating impact assessment results against two benchmarks are as follows;

vs. Building New	vs. UBC New Academic Building Average	Impact description
49% less	36% less	fossil fuels consumed
85% less	87% less	weighted resource use impacts
62% less	56% less	global warming substances emitted
57% less	50% less	acidifying substances emitted
44% less	51% less	human health respiratory system impacting substances emitted
74% less	69% less	eutrophying substances emitted
55% less	73% less	ozone layer depleting substances emitted
60% less	52% less	smog forming substances emitted

The results above detail the benefits of renovating a post-secondary institutional building rather than building new (Building New scenario) with and without the demolition of an existing structure (UBC Academic Building Average) at the UBC Vancouver campus. The estimated avoided impacts were on average 60% of the Building New scenario and 30% of the UBC Academic Building Average. An

average of 90% of the impact assessment results were caused by the resource extraction and manufacturing of new construction products, of which the wall assemblies were responsible for an average of 73% and 48% of the Renovating and Building New scenario results respectively.

Lastly, two sensitivity analyses were carried out to investigate the robustness of the study results. The first demonstrated the sensitivity of avoided impact results when using hypothetical building assembly types in the comparison. The Building New scenario's impact assessment results sensitivity to changes in wall type and height reduced the avoided impacts of Renovating rather than Building New by an average of 5%. The second sensitivity analysis demonstrated that the Renovation scenario could outperform new construction even when there is no need to demolish an existing structure, as it had the seventh lowest cradle to gate impacts amongst thirty UBC academic buildings and the lowest among the four constructed to LEED standards.

This BioSciences LCA report provides a transparent communication of the environmental benefits of renovating the BioSciences building. The level of detail of this report allows for reproducibility which is a key educational asset for those involved in environmental assessments of building construction practices at UBC and beyond.

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1. Introduction

1.1 Purpose of Study

The south and west wings of the UBC Biological Science Complex (BioSciences Building) were recently renovated as part of the Renew Project, a public-private partnership between the Province of British Columbia and the University of British Columbia (UBC) to upgrade aging buildings at the UBC Vancouver campus.

The UBC department managing the Renew Project, UBC Project Services, requested a life cycle assessment (LCA) study be carried out to transparently communicate the environmental benefits of their decision to upgrade the existing BioSciences Building by renovating rather than demolishing and building new. This study is also to be used as a capacity building asset to contribute to the development of LCA into sustainable construction practices at UBC, as LCA is rapidly gaining acceptance at all scales of sustainable construction standards[1,2,3,4] and corporate social responsibility policies[5,6,7].

In conjunction with international standards[8], the Athena Sustainable Materials Institute (Athena Institute) in association with Recollective Consulting has completed an LCA of the BioSciences Building Renew Project to quantify the environmental implications of the decision to renovate rather than build new. Complete documentation of its development and use of the Environmental Impact Estimator LCA software are included in this study in order to ensure that it is both transparent and reproducible.

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[1] LEED NC 2009 IDc1: Innovation Design - http://www.leeduser.com/credit/NC-2009/IDc1
[2] LEED 2012 Pilot - https://www.usgbc.org/ShowFile.aspx?DocumentID=8182
[3] ASHRAE 189.1 - http://www.ashrae.org/publications/page/927
[2] LEED 2012 Pilot - https://www.usgbc.org/ShowFile.aspx?DocumentID=8182
[4] ISO 21931-1 - http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=45559
[3] ASHRAE 189.1 - http://www.ashrae.org/publications/page/927
[4] ISO 21931-1 - http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=45559
[5] Sustainability Consortium - http://www.sustainabilityconsortium.org/members/
[6] Sustainable Product Index - http://walmartstores.com/pressroom/news/9277.aspx
[7] Earthster - http://earthster.org/content/nov-9-free-webinar-earthster-debuts-open-source-lca-tool-piloted-walmart-seventh-generation
[8] ISO 14040:2006, *Environmental Management - Life Cycle Assessment - Principles and Framework* and ISO 14044:2006, *Environmental Management - Life Cycle Assessment – Requirements and Guidelines*.

1.2 Project Description

The Biological Sciences Complex is located in the heart of the UBC Vancouver campus at the western edge of Vancouver in British Columbia, Canada.

Two wings of the Biological Sciences Complex that house the departments of Zoology and Botany have been upgraded. The work was geared to meeting deferred maintenance and future academic and research needs, optimizing space and determining the most advantageous life cycle costs while meeting service objectives, current codes and technical standards. Significant improvements in energy efficiency have been achieved through upgrades to mechanical systems, lighting and fenestration. The sum of these upgrades is targeting LEED Gold certification under version 1.0 plus addenda.

The upgrade work consists of the South Wing (54,030 square feet) constructed in 1957, and the West Wing (97,628 square feet) constructed in 1970. Together, these buildings house research labs, classrooms, teaching labs, computer labs, academic and administrative offices, student support services, imaging and aquatic animal facilities.

The majority of the structure and cladding is maintained, with upgrades for improved thermal performance. In addition to the extensive improvements to mechanical and electrical systems, the scope of the project included entirely gutting and then upgrading the interiors and some exterior cladding. In addition to the interior and envelope upgrades, work outside the building has been done to replace vegetation with adaptive and native species and provide stormwater management.

This LCA aims to capture the environmental implication of renovating rather than building new as they relate to the structure and envelope of the BioSciences Building. The reason for this focus was that both buildings would have been constructed to operate at the same performance during its use regardless of whether it was renovated or built new. Thus, impacts occurring beyond the construction of the buildings were left outside the scope of this study.

The resulting LCA study investigated two scenarios – Renovating and Building New. The Renovating scenario involved the partial demolition of the existing building and construction of a Renovated BioSciences Building, while the Building New Scenario involved the full demolition of the existing building and construction of a Built New BioSciences Building. The structures and envelopes of the respective new BioSciences Buildings studied in each scenario are summarized in Table 1.

Table 1 Renovated and Newly Built BioSciences Building Characteristics.

Building System	Renovated BioSciences Building Characteristics	Newly Built BioSciences Building Characteristics
Structure	West Wing: Concrete structure with concrete columns South Wing: Concrete structure with concrete columns and beams	West Wing: Concrete structure with concrete columns South Wing: Concrete structure with concrete columns and beams
Floors	West Wing: Concrete Precast Double T floors and partial Slab on Grade in the basement South Wing: Suspended Concrete Slab floors and partial Slab on Grade in the basement	West Wing: Concrete Precast Double T floors and Slab on Grade in the basement South Wing: Suspended Concrete Slab floors and Slab on Grade in the basement
Exterior Walls	All foundations: Cast in Place Concrete West Wing: Tilt Up concrete sections with stucco exterior cladding and Cast in Place concrete walls South Wing: Concrete Block Walls with standard brick cladding and cement plaster on concrete structure	All foundations: Cast in Place Concrete West Wing: Tilt Up concrete sections with stucco exterior cladding and Cast in Place concrete walls South Wing: Concrete Block Walls with standard brick cladding and cement plaster on concrete structure
Interior Walls	Both Wings: Steel Stud with 5/8” gypsum wall board and Interior Glass walls	West Wing: Steel Stud with gypsum wall board South Wing: Concrete Block Wall with plaster on structure
Windows	All windows: Aluminum framed with low E tin argon filled Glazing	All windows: Aluminum framed with standard glazing
Roof	All roofs: 2 ply sbs high albedo membrane, barrier board, rigid insulation varying between 50-200mm thick and a vapour retarder.	All roofs: 2 ply sbs high albedo membrane, barrier board, rigid insulation varying between 50-200mm thick and a vapour retarder.

Two main methods were used in this LCA study in order to provide a complete and valid life LCA of the BioSciences scenarios describe above. These methods included;

- Following the International Organization for Standardization (ISO) standards 14040 and 14044
- Using of the Environmental Impact Estimator LCA software

The following sections introduce and provide general insight into these methods.

2. Overview of Methods

2.1 Introduction to Life Cycle Assessment Methodology

Life cycle assessment (LCA)[9] is an analytical tool used to comprehensively quantify and interpret the environmental flows to and from the environment (including emissions to air, water and land, as well as the consumption of energy and other material resources), over the entire life cycle of a product (or process or service). By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product and an accurate picture of the true environmental trade-offs created by design decisions and product selection.

The international standards in the ISO 14040-series[10] set out a four-phase methodology framework for completing an LCA, as shown in Figure 1: (1) goal and scope definition, (2) life cycle inventory, (3) life cycle impact assessment, and (4) interpretation.

Goal and Scope: An LCA starts with an explicit statement of the goal and scope of the study, the functional unit, the system boundaries, the assumptions and limitations and allocation methods used, and the impact categories chosen. The goal and scope includes a definition of the context of the study which explains to whom and how the results are to be communicated. The goal and scope of an LCA shall be clearly defined and shall be consistent with the intended application. The functional unit is quantitative and corresponds to a reference function to which all flows in the LCA are related.

Life Cycle Inventory (LCI): In the inventory analysis, a flow model of the technical system is constructed using data on inputs and outputs. The flow model is often illustrated with a flow chart, which includes the activities that are going to be assessed and also gives a clear picture of the technical system boundary. The input and output data needed for the construction of the model are collected (such as resources, energy requirements, emissions to air and water, and waste generation for all activities within the system boundaries). Then, the environmental loads of the system are calculated and related to the functional unit, and the flow model is finished.

Life Cycle Impact Assessment (LCIA): Inventory analysis is followed by impact assessment - where the LCI data are characterized in terms of their potential environmental impact (e.g., acidification, eutrophication, and global warming potential effects). The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI results. In the classification stage, the inventory parameters are sorted and assigned to specific impact categories.

The calculation of indicator results (characterization) involves the conversion of LCI results to common units and the aggregation of the converted results within the same impact category. This

[9] This introduction is based on international standards in the ISO-14040 series, *Environmental management – Life Cycle Assessment*.

[10] ISO 14040:2006, *Environmental Management - Life Cycle Assessment - Principles and Framework* and ISO 14044:2006, *Environmental Management - Life Cycle Assessment – Requirements and Guidelines*. Note that ISO 14041, ISO 14042, and ISO 14043 have been withdrawn.

conversion uses characterization factors. The outcome of the calculation is a numerical indicator result typically stated on an equivalence basis.

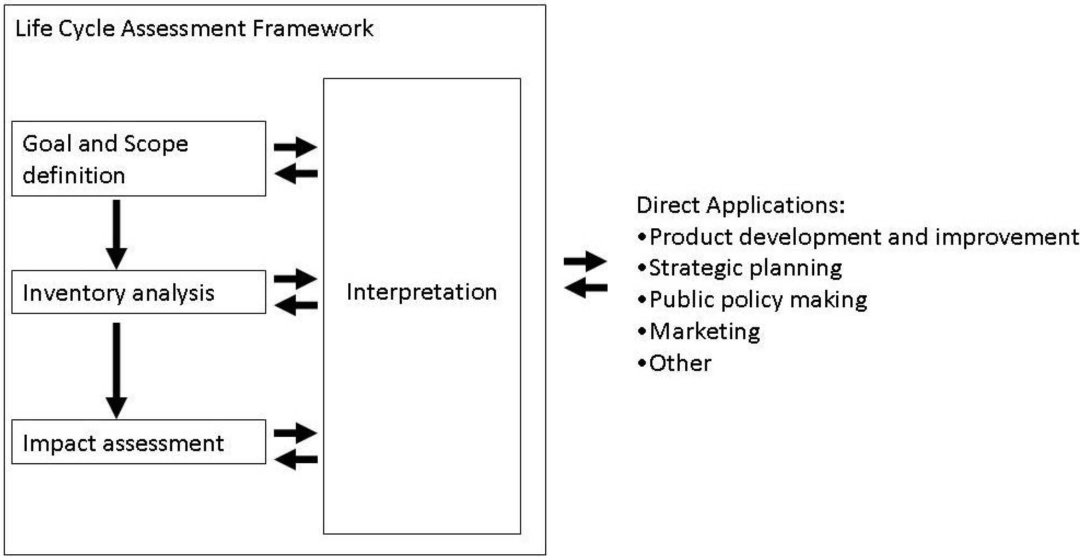

Figure 1 The four stages of life cycle assessment.

Interpretation: The results from the inventory analysis and impact assessment are summarized during the interpretation phase. According to ISO 14040:2006 the interpretation should include:

- Identification of significant issues for the environmental impact;
- Evaluation of study considering completeness, sensitivity and consistency; and
- Conclusion and recommendations.

The working procedure of LCA is iterative as illustrated with the back-and-forth arrows in Figure 1. The iteration means that information gathered in a later stage can cause effects in a former stage. When this occurs the former stage and the following stages have to be reworked taking into account the new information. Therefore it is common for an LCA practitioner to work at several stages at the same time.

If the LCA results are to be used for “comparative assertions”, the ISO 14044[11] protocol requires additional LCA rigor and transparency to be employed, especially if the resulting LCA will be disclosed to the public. The ISO protocol offers additional guidance and requires another level of analysis to support comparative assertions and most importantly requires a critical review. A comparative assertion study requires *all products* to be treated equally and be of similar quality to stand up to the critical review process. All comparisons need to be completed using the same functional unit and

[11] ISO 14040:2006, *Environmental Management - Life Cycle Assessment - Principles and Framework* and ISO 14044:2006, *Environmental Management - Life Cycle Assessment – Requirements and Guidelines*. Note that ISO 14041, ISO 14042, and ISO 14043 have been withdrawn.

equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures, decisions for evaluating inputs inclusion and exclusion, and impact assessment. Data quality also needs to be addressed to satisfy the ISO "consistency check".

2.2 Introduction to Impact Estimator

The Athena Environmental Impact Estimator (Impact Estimator or IE) software was used to develop LCA models that estimate the impacts created by the material and energy usage of the New BioSciences Building scenarios. The Impact Estimator was selected for use in this study because it is the only software tool with the capacity to assess the life cycle impacts of whole buildings and assemblies, based on internationally recognized life cycle assessment (LCA) methodology, in North America.

The Impact Estimator is designed to help architects, engineers and others building professionals assess and compare the environmental implications of industrial, institutional, commercial and residential building designs — both for new buildings and major renovations. Where relevant, the software also distinguishes between owner-occupied and rental facilities.

The IE puts the environment on equal footing with other more traditional design criteria at the conceptual stage of a project. It is capable of modeling 95% of the building stock in North America and is capable of estimating the environmental impacts of the following processes:

- Material manufacturing, including resource extraction and recycled content
- Related transportation
- On-site construction
- Regional variation in energy use, transportation and other factors
- Building type and assumed lifespan
- Maintenance and replacement effects
- Demolition and disposal

Although the Impact Estimator doesn't include an operating energy simulation capability, it does allow users to enter the results of a simulation in order to compute the fuel cycle burdens, including pre-combustion effects, and factors them into the overall results.[12]

[12] Impact Estimator for Buildings - http://www.athenasmi.org/tools/impactEstimator/index.html

2.2.1 Impact Estimator Basic Workflow

LCA models are developed in the Impact Estimator (IE) as users input qualified and quantified materials estimate information to define the design of the building. Information is qualified in a number of ways, including the city that the building is located in, the building type and the assembly types (ie. for walls, floors, roof, foundations and columns & beams) contained within it. Quantified information includes the building service life, how much energy is consumed in operation, and assembly attributes including wall length, height, number of windows, etc. Once this information is entered, electricity grid mixes and transportation matrices are applied based on location, maintenance cycles are applied based on the building service life, and algorithms are then applied to the inputted materials information in order to complete the takeoff process and generate a bill of materials (BoM).

The calculated energy demand and BoM (including materials required for maintenance) then references the Athena Life Cycle Inventory (LCI) Database, in order to generate a cradle-to-grave (ie. extraction to end of life) LCI profile for the building. The IE then filters these LCI results through a set of characterization factors based on the midpoint impact assessment methodology developed by the US Environmental Protection Agency (US EPA), called the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI), and one developed by the Athena Institute to produce impact assessment results.

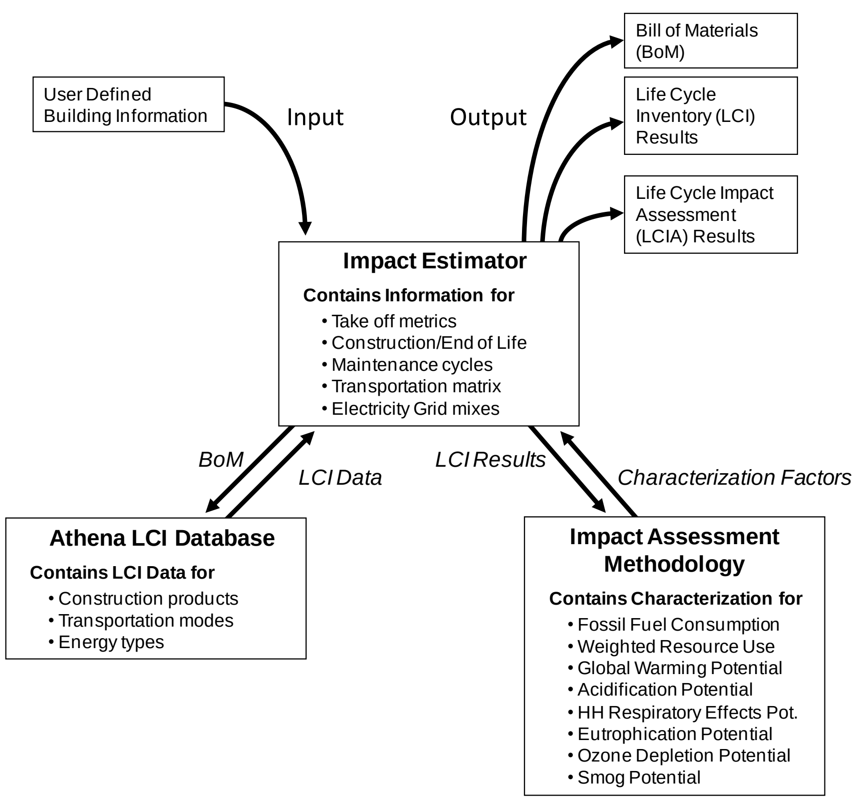

Figure 2 Impact Estimator basic workflow from user defined inputs to LCA results.

3. BioSciences LCA Study

In accordance with the ISO 14040 and 14044 standards, this report will provide sections to describe the Goal and Scope, provide a summary of the Inventory Analysis and Impact Assessment Results as well as a summary of findings, concluding remarks and recommendations in an Interpretation section on page 19.

The following Goal and Scope section outlines the details of the LCA study that was carried out on the Biological Sciences Complex (BioSciences building) Renew Project. All of the details of this study are explicitly outlined in the Goal & Scope section below.

3.1 Goal & Scope

The Goal & Scope is critical to documenting the context and guiding an LCA study's execution. The purpose of defining the Goal of the study is to unambiguously state the context of the study, whereas the Scope details how the actual modeling of the study was carried out. For this BioSciences LCA study report, the format immediately below has been used to unambiguously outline the details of the parameters outlined in ISO 14040 and 14044.

Parameter Name

Parameter definition.

Details of how this item is defined for the BioSciences LCA study.

This format has been followed throughout the Goal & Scope in order to provide the audience with an explanation each parameter and transparently state how it is defined for the BioSciences LCA study.

3.1.1 Goal of Study

The following are descriptions for a set of parameters which unambiguously state the context of the BioSciences LCA study.

Intended application

Describes the purpose of the LCA study.

This LCA study will be used in two ways:

- as a transparent marketing tool to communicate the benefits of renovating the Existing BioSciences Building rather than completely demolishing it and constructing a completely New BioSciences Building.
- as an exemplary demonstration of the latest in environmental impact accounting methods in order to contribute to the further development of such activities.

Intended audience

Describes those who the LCA study is intended to be interpreted by.

The results of this study are to be primarily communicated to the public. In addition to the general public, the LCA report is intended to be communicated to industry and governments groups observing and involved in green building, as LCA is an emerging topic of significance in this area.

Intended for comparative assertions

State whether the results of this LCA study are to be compared with the results of other LCA studies.

The results of this LCA study are intended for comparative assertions between the two BioSciences scenarios as well as with the building LCA studies contained within the UBC LCA Database. Its results are not intended for comparative assertions external to this BioSciences LCA study as it has been carried out for the specific applications outlined in the intended application above.

3.1.2 Scope of Study

The following are descriptions for a set of parameters that detail how the actual modeling of the study was carried out.

Product system to be studied

Describes the collection of unit processes that will be included in the study.

A unit process is a measurable activity that consumes inputs and emits outputs as a result of providing a product or service. The main processes that make up the product system to be studied in this LCA study are the demolition of a building (Figure 3), the manufacturing of construction products (Figure 4) and the construction of a building (Figure 5). These three processes are the building blocks of the LCA models that have been developed to describe the impacts associated with the two BioSciences Building scenarios (i.e. Renovating and Building New). The unit processes and inputs and outputs considered within these three main processes are outlined below.

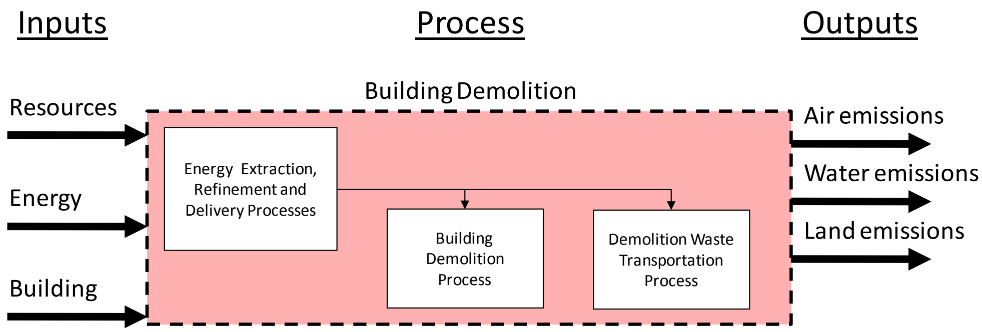

Figure 3 Generic unit processes considered within Building Demolition process by Impact Estimator software.

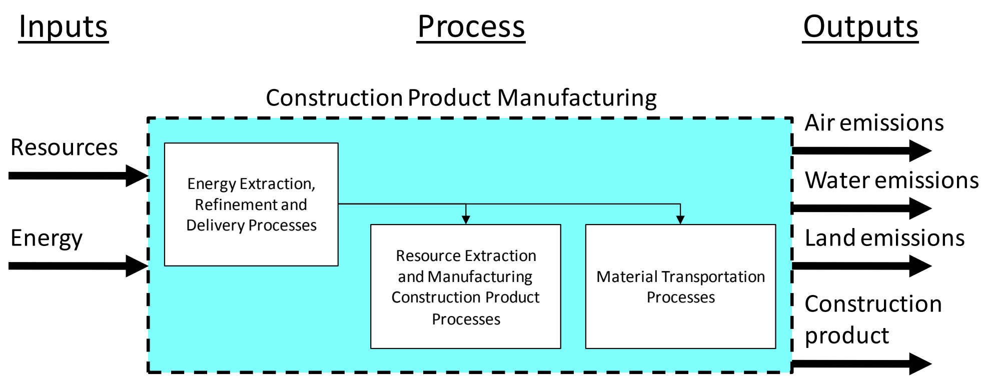

Figure 4 Generic unit processes considered within Construction Product Manufacturing process by Impact Estimator software.

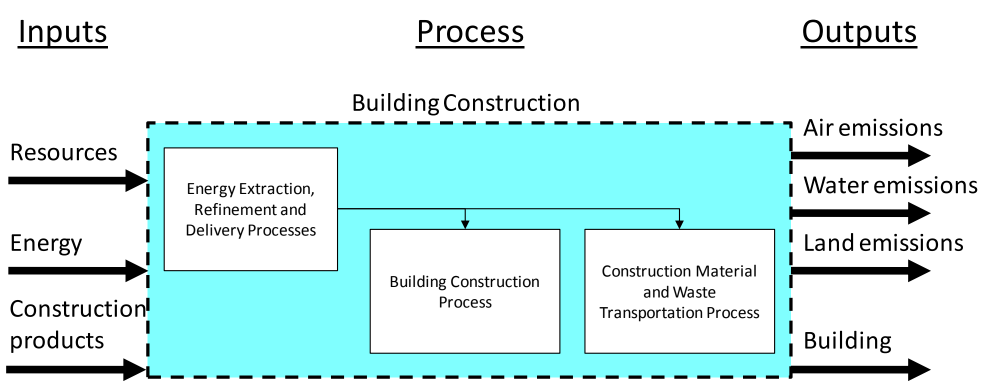

Figure 5 Generic unit processes considered within Building Construction process by Impact Estimator software.

As seen in the above figures, the inputs and outputs occurring at the various stages in a buildings life cycle are captured. That is, the building demolition unit process capture the grave (i.e. end of life) and the construction product manufacturing and building construction processes capture

the cradle to gate (i.e. resource extraction, manufacturing construction products and construction of a building). The organization of these processes into the product systems to describe the impacts of renovating rather than building new require the definition of a system boundary. Thus, the product system studied in this BioSciences LCA study is further defined in the system boundary section below.

System boundary

Details the extent of the product system to be studied in terms of product components, life cycle stages, and unit processes.

The BioSciences LCA study involved the development of two scenarios – Renovation and Building New (Figure 6). In the Renovation scenario, the Existing Building is partially demolished and a Renovated New Building is partially constructed. In the Building New scenario the Existing Building is fully demolished and a Newly Built Building is fully constructed. The LCA models developed to describe the impacts created by these scenarios were created in the Impact Estimator software using the unit processes, within the main processes, illustrated previously in Figure 3, Figure 4 and Figure 5.

The products studied in both of these scenarios are the Existing, Renovated New and Newly Built BioSciences Buildings. Specifically, this study includes the construction products used to create their structures and envelopes. This indicates that product components must be defined the materials within the products studied.

The material product components (i.e. building assemblies) that were included from the products (i.e. buildings) are the footings, slabs on grade, walls, columns and beams, roofs, as well as all associated doors and windows, gypsum board, vapour barriers, insulation, cladding and roofing. These material product components are in turn assemblies of construction products.

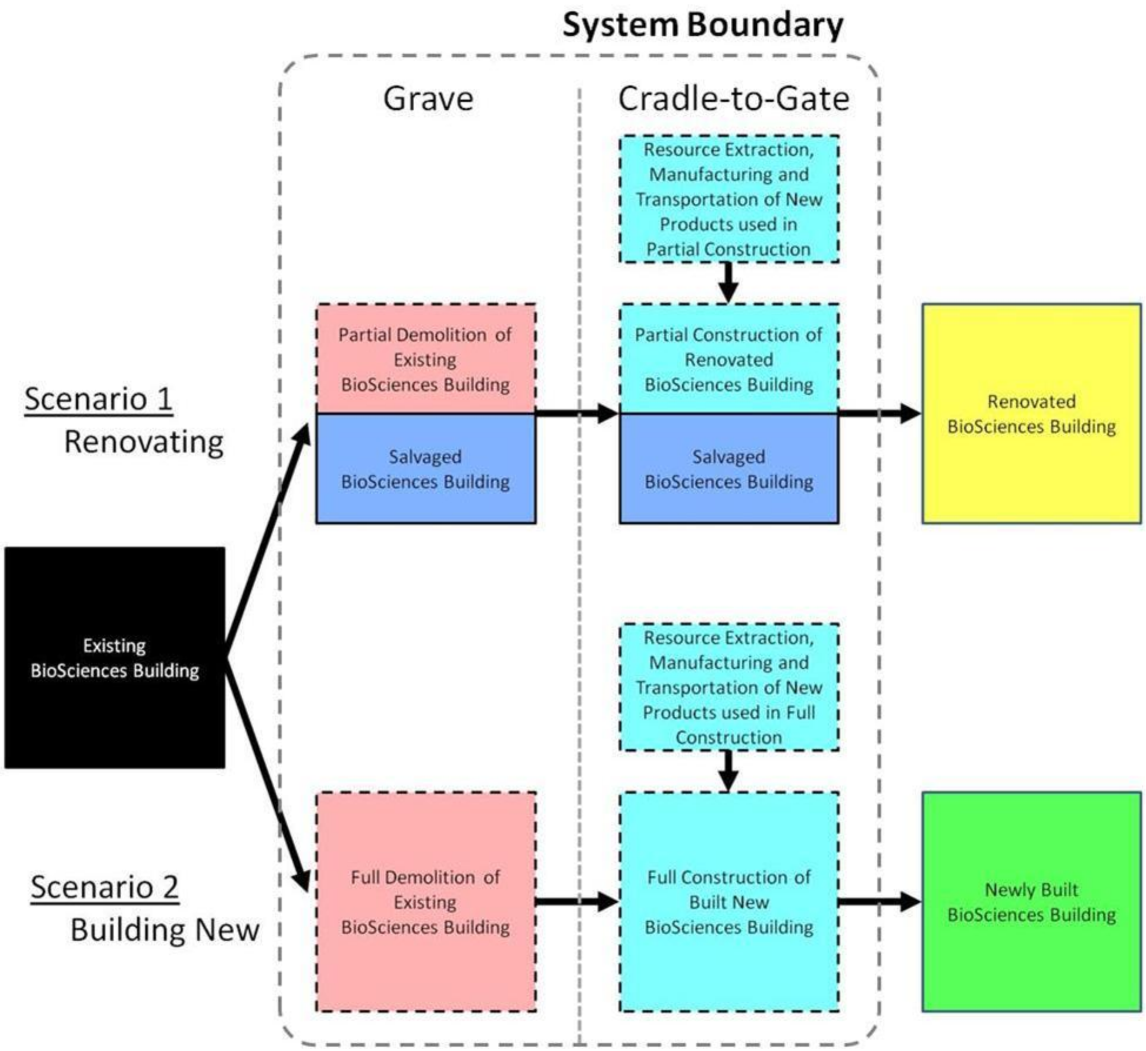

Figure 6 System boundary for Renovation and Building New scenarios.

The life cycle stages considered in the Renovating and Building New scenarios include those spanning from cradle-to-grave. However, both scenarios begin with a grave life cycle phase which captures the demolition of the Existing BioSciences building and the transportation of demolition wastes to their end-of-life scenarios. Then a model for the cradle-to-gate phase captures the resource extraction and manufacturing of construction products as well as the building construction process. As a result of these processes, the final output from each scenario are two respective new BioSciences buildings – Renovated and Built New.

Functions of the product system

Describes the functions served by the product focused on in the LCA study.

The New BioSciences Buildings modeled in this LCA are designed to fulfill two main functions. The first is as safe and climate controlled buildings that separate their occupants and structures from the environment. The second is as an academic institutional building on the University of British Columbia Vancouver campus.

Functional unit

A performance characteristic of the product system being studied that will be used as a reference unit to normalize the results of the study.

As the square foot floor areas of the Renovated and Built New BioSciences Buildings do not significantly differ in square footage or function, the primary functional units used in this study to normalize the LCA results for the material components of the BioSciences Buildings are *per post-secondary academic building constructed*.

Secondary functional units are used in a comparison with academic buildings of similar function whose square footage differs significantly from that of the New BioSciences Building. In this comparison functional units of *per square foot post-secondary academic building constructed* are used to enable the results to be equated on an equal footing.

Allocation procedures

Describes how the input and output flows of the studied product system (and unit processes within it) are distributed between it and other related product systems.

The problem of allocation arises in three situations – i) when a process produces more than one product, ii) a waste treatment process collectively treats multiple wastes products and iii) when materials are recycled or reused in subsequent life cycles. An allocation problem arises in these situations because the input and output flows from the processes must be shared amongst the products and subsequent life cycles.

Allocation was required in the BioSciences LCA study as the scope of the life cycle stages that were considered straddles the end of life of the Existing BioSciences Building and the cradle to gate of the new BioSciences buildings. This allocation problem is described by situation iii) above, as the Existing BioSciences Building is an output flow from a previous life cycle and also an input to the creation of new BioSciences Buildings in both scenarios. In this study, the cut-off allocation method was used, which entails that only the impacts directly caused by a product within a given life cycle stage are allocated to that product. The details of how the cut off method was applied are detailed below.

The allocation problem in both scenarios is two-fold: First, to establish which life cycle bares the impacts of the initial manufacturing of the BioSciences Building. Second, in the Building New scenario, to establish which life cycle assumes the impacts of demolition.

The result of applying the cut-off allocation method is that the manufacturing of the initial BioSciences Building is allocated to previous life cycle and is thus outside the system boundary of both the Building New and Renovated scenarios. The demolition effects in the Building New scenario are allocated entirely to the life cycle under consideration in this study. Including the demolition effects in the Building New life results is essential to capture the additional impacts caused by this process as one of the primary differences between the two scenarios is both the manufacturing and demolition of additional materials.

Although construction and demolitions wastes are direct outputs from both scenarios, their potential subsequent life cycles were outside the scope of this LCA study. That is, the end of life phase ends once the wastes are transported to their end of life process, and does not include consideration of waste treatment processes or possible subsequent life cycles.

Impact assessment methodology and categories selected

State the methodology used to characterize the LCI results and the impact categories that will address the environmental and other issues of concern.

The primary impact assessment methodology used in the BioSciences LCA study was the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI), developed by the US Environmental Protection Agency (US EPA). The impact assessment methodology developed by the Athena Institute was also used to characterize weighted raw resource use and fossil fuel consumption.

The impact categories selected and the units used to express them (i.e. category indicators) are listed below.

- Global warming potential – kg CO_2 equivalents
- Acidification potential – H^+ mol equivalents
- Eutrophication potential – kg N equivalents
- Ozone depletion potential – kg CFC^{-11} equivalents
- Photochemical smog potential – kg NOx equivalents
- Human health respiratory effects potential – kg $PM_{2.5}$ equivalents
- Weighted raw resource use – kg
- Fossil fuel consumption – MJ

The definitions from the Impact Estimator for each of these impact categories are listed in Appendix A.

Data sources

Explicit statement of all data sources used to measure, calculate or estimate information from in order to complete the study of the product system.

Two main data sources were used to develop the LCA models for this study – building assemblies and those contained within the Impact Estimator.

Measurements, calculations and estimates of the building assemblies (i.e. floors, walls, roof, etc.) were derived from the architectural and structural drawings in order to develop the model that produced the grave life cycle phase of the Existing BioSciences Building used in both scenarios. Architectural and structural drawings were obtained from Acton Ostry Architects to develop information on the building assemblies in the partial construction of the Renovated BioSciences Building. Information on the building assemblies in the full construction of the Newly Built BioSciences Building were developed from the original architectural and structural drawings. However, two key updates were made – 1) an increase in the floor to floor height from 3.2 m to 4 m and 2) change the roof envelope from an asphalt roofing system to a modified bitumen roofing system to match the Newly Built BioSciences Building design. The resulting building assembly information for all of the scenarios is contained in the respective Input Documents in Appendix B.

All of the material take off, LCI and transportation networks information used in this study have been developed by the Athena Institute and are built into the Impact Estimator version 4.1.13. Companion LCI documents are available on the Athena Institute webpage (www.athenasmi.org) which provide some insight into how of this information was developed.

Assumptions

Explicit statement of all assumptions used to by the modeler to measure, calculate or estimate information in order to complete the study of the product system.

As with data sources, there were two main areas where assumptions were required – building assemblies and those contained within the Impact Estimator.

All instances where assumptions regarding the measurement, calculation and estimate of the building assemblies for both of the building scenarios are indicated in the respective Input Documents in Appendix B and the details to those assumptions are found in the Assumptions Documents contained in Appendix C. Assumptions were typically required in the development of building assembly information due to missing information as well as limitations in construction product LCI data and assembly characteristics in the Impact Estimator.

Assumptions regarding the completion of take offs to estimate material use, referenced LCI data and transportation networks have all been developed by the Athena Institute and are built into the Impact Estimator version 4.1.13. This information is proprietary; however, parts can be accessed through the inner workings report found on the Athena Institute webpage.[13]

Limitations

Describe the extents to which the results of the modeling carried out on the product system accurately estimate the impacts created by the product system defined by the system boundary of the study.

The following limitations should be considered when interpreting the results of this LCA study.

System Boundary – Any of the impacts created or avoided through the reuse, recycling or waste treatment of the construction or demolition wastes emitted were outside the system boundary of this study.

Data Sources and Assumptions – This LCA study used the architectural and structural drawings from the Existing and Renovated New BioSciences Buildings. The resulting LCA models are specific to these buildings as their bills of materials reflect their unique designs. Furthermore, the life cycle inventory (LCI) data and modeling assumptions built into the Impact Estimator create some geographic and temporal limitations on the ability of this study to predict the impacts of other future post-secondary academic institutional buildings. For instance, i) The construction product manufacturing as well as fuel refining and production LCI data is based on North American averages ii) The transportation matrix that estimates distances and modes for construction product transportation as well as construction and demolition wastes is specific to Vancouver, British Columbia iii) The LCI data and modeling parameters in the Impact Estimator were developed by the Athena Institute to reflect current circumstances and technologies.

This study has not been prepared for comparative assertions with buildings outside those outlined within this report. It is advised that the authors be contacted if one wishes to include or use these results in future circumstances outside those outlined in the intended application for this study.

[13] The Inner Working of the Impact Estimator for Buildings: Transparency Document - http://www.athenasmi.org/tools/impactEstimator/innerWorkings.html

4. Results

The LCA study carried out in accordance with the Goal & Scope documented in the previous section and summarized in this report compares the environmental performance of the actual renovated BioSciences building's design under a certain set of assumptions against reference building designs using roughly the same set of assumptions. This study included the development of two LCA models in the Impact Estimator of the Renovating and Building New scenarios which produced inventory analysis and impact assessment results. These results should be considered a best estimate as they cannot exactly predict environmental impacts due to the extensive number of approximations and assumptions in the modelling process and the uncertainties of actual building life cycle impacts.

Thus, in addition to the Goal & Scope, all results and the inputs and assumptions that created them are diligently detailed and included in this report in order to ensure transparency and reproducibility of this study and its results. All results from this LCA study can be reproduced in the Impact Estimator by following the Inputs Documents contained in Appendix B and all associated modeling assumption can be referenced in the Inputs Assumptions Documents in Appendix C. All of Inputs and Inputs Assumptions Documents are named consistently with the product system defined within the boundaries illustrated in Figure 6. Table 2 details the organization of these documents by the life cycle stages they modeled in each of the BioSciences scenarios.

Table 2 Organization of Inputs and Inputs Assumptions Documents for BioSciences scenarios.

Scenario	Input and Inputs Assumptions Documents	Life Cycle Stages Modeled		
		Manufacturing	Construction	End of Life
Renovation	Partial Demolition of Existing BioSciences Building			●
	Partial Construction of New BioSciences Building	●	●	
Building New	Existing Building Inputs Document			●
	Full Construction of New BioSciences Building	●	●	

For the purposes of maintaining transparency, contributing to furthering LCA activities and reducing the length of this report all results for inventory analysis and impact assessment are contained in the Appendix D and Appendix E, which will be subsequently referred to through discussion of the results in the following Interpretation chapters.

5. Interpretation

This section provides discussion of the development and results of the LCA study being summarized in this report in order to ensure that complete and valid claims are made to support the intended purpose of this LCA study. Following these discussions are some conclusions and recommendations for future efforts to study the impacts of renovating versus building new.

5.1 Scenario Model Development

It is appropriate at this juncture before discussing the results to revisit the development of the design and product specifications incorporated into both scenarios in order to gain further insight into the robustness of their resulting inventory analysis and impact assessment estimates. The following is a discussion of how the respective New BioSciences Building designs were developed in each of the Renovating and Building New scenarios.

The Renovated BioSciences Building design and material specifications being considered in the Renovating scenario is based on the actual architectural and structural drawings for the as-built New BioSciences Building that has actually been constructed. These drawings clearly indicated which portions of the building were to be selectively demolished and detailed the ensuing construction of the Renovated BioSciences Building. Thus, the inventory analysis and impact assessment results from this LCA model should be considered accurate given currently available information on the Renovated BioSciences Building as well as available life cycle inventory data, impact assessment methods and LCA software capabilities.

In the Building New scenario, it was unfeasible to create completely a new design with material specifications for a Newly Built BioSciences Building. The resulting decision was to base the development of this LCA model on the Existing Building with updates on two building characteristics – 1) increase in the floor to floor height from 3.2 to 4 meters to reflect a likely update in the design, and 2) change the roof envelope from an asphalt roofing system to a modified bitumen roofing system to match the Newly Built BioSciences Building. Of course, it should be considered that it is unlikely the case that a Newly Built BioSciences Building constructed in the footprint of a fully demolished Existing BioSciences Building would adopt the exact same design with only these two updates. Thus, the comparisons of LCA results between the Renovating and Building New scenario should be considered best estimates given the limited time and resources available to be invested in completely redesigning a Newly Built BioSciences Building specifically for use in this LCA study.

As indicated in this discussion, the Renovating scenario results are quite robust relative to those of the Building New scenario. In recognition of this, the following sections begin by providing discussion on the primary results of this LCA study (i.e. Renovating vs. Building New), and then move on to a sensitivity analysis section where further comparisons are investigated with the Renovating scenario in order to see how they affect the avoided impact results.

5.2 Inventory Analysis

The following is an interpretation of the comparison made between the Renovated and Building New scenario inventory analysis results for resource use – which describes all of the raw resources that were consumed as inputs by the various processes within the product system studied in the Renovating and Building New scenarios (see Figure 3, Figure 4 and Figure 5).

In both scenarios it was the cradle to gate demand for new construction products and the construction of new BioSciences Buildings. BoMs detailing the construction products consumed in the respective construction and demolition activities in both the Renovated and Building New scenarios are contained in Table 17 and Table 18 in Appendix D. As the majority of construction products were consumed as a direct result of the design and product specification decisions for the Renovated and Newly Built BioSciences Buildings, Table 19 and Table 20 in Appendix D provide further insight into the BoMs of these buildings at the assembly level in order to provide insight into the products and where they were used in the buildings.

Once of the immediate outcomes of the demand for construction product is the need to extract resources to include as material and energy process inputs. The cradle to gate resource demands of the manufacturing and construction processes consumed approximately 95% of the total resources used, by weight, in both scenarios. This is primarily due to the demolition processes requiring mainly energy inputs to transport material to their end of life processes. Table 3 provides a detailed comparison between cradle to gate resource inputs used to satisfy the construction product manufacturing, transportation and construction process demands created by the new BioSciences Buildings in the Renovating and Building New Scenarios.

The most notable avoided resource use seen in Table 3 include approximately 4 million L of water, 16 tonnes of coal, 280,000 m^3 of natural gas and 120,000 L of crude oil. A full breakdown of Table 3 into manufacturing and construction resource use by assembly group can be found in Appendix D.

Avoiding the use of these raw resources outlined above in turn reduces the amount of resource extraction, energy use as well as avoided environmental and human health impacts. The following section provides further insight into these avoided impacts as they relate to the production of the Renovated and Newly Built BioSciences Buildings in the Renovating and Building New scenarios.

Table 3 Comparison of total resource use to manufacture construction products, transport and construct new BioSciences Buildings in the Renovating and Building New scenarios.

Resource	Units	Manufacturing Products and Constructing New BioSciences Building Total Resource Use Results		Difference	
		Renovating	Building New	Absolute	Percent
Limestone	tonnes	286	2,539	**-2,253**	**-88.7%**
Clay & Shale	tonnes	63	838	**-775**	**-92.5%**
Iron Ore	tonnes	68	102	**-34**	**-33.5%**
Sand	tonnes	47	171	**-124**	**-72.7%**
Ash	tonnes	2	21	**-19**	**-91.3%**
Gypsum	tonnes	138	138	**-0**	**-0.2%**
Semi-Cementitious Material	tonnes	16	153	**-137**	**-89.8%**
Coarse Aggregate	tonnes	550	5,489	**-4,939**	**-90.0%**
Fine Aggregate	tonnes	416	5,060	**-4,644**	**-91.8%**
Water	L	6,032,135	9,981,288	**-3,949,153**	**-39.6%**
Obsolete Scrap Steel	tonnes	42	401	**-359**	**-89.5%**
Coal	tonnes	202	217	**-16**	**-7.1%**
Wood Fiber	tonnes	3	38	**-35**	**-92.6%**
Natural Gas	m3	103,577	382,341	**-278,764**	**-72.9%**
Natural Gas as feedstock	m3	26,548	26,829	**-281**	**-1.0%**
Crude Oil	L	109,787	232,866	**-123,078**	**-52.9%**
Crude Oil as feedstock	L	152,153	157,672	**-5,519**	**-3.5%**
Metallurgical Coal as feedstock	tonnes	26	15	**11**	**76.0%**
Prompt Scrap Steel as feedstock	tonnes	26	256	**-230**	**-89.9%**

5.3 Impact Assessment

The following is an interpretation of comparisons made between the Renovated and Building New scenario impact assessment results.

Many resources and significant amounts of energy are consumed as a result of the demolition, resource extraction and manufacturing, construction and transportation processes within the product systems modeled. As a direct result of this consumption, significant amounts of substances are emitted to air, water and land. Considering these inputs and outputs only as inventory analysis results limits the amount of insight into their significance in terms of the potential damage they may be creating as a result of being released into the environment. Providing a context for this potential damage is the purpose of the impact assessment stage.

In an LCA study, the impact assessment stage essentially involves grouping inventory analysis results into specified impact categories (see Appendix A for impact category definitions) and characterizing them based on their potential to do damage through resource extraction activities, the amount of non renewable fossil fuel they've consumed as process energy and their potential to cause damaging reactions in various areas of the environment and human health. The result of the characterization of the inventory analysis results for each of the BioSciences Building scenarios in the impact assessment stage of this LCA study are detailed in Table 4.

Table 4 Comparison of Renovating and Building New Scenarios total impact assessment results.

Impact Category	Category Indicator	Scenario Total Impact Assessment Results		Difference	
		Renovating	Building New	Absolute	Percent
Fossil Fuel Consumption	MJ	2.45E+07	4.85E+07	**-2.4E+07**	**-49.4%**
Weighted Resource Use	kg	2.70E+06	1.80E+07	**-1.5E+07**	**-85.0%**
Global Warming Potential	kg CO_2 eq	1.43E+06	3.78E+06	**-2.4E+06**	**-62.2%**
Acidification Potential	moles of H^+ eq	6.67E+05	1.53E+06	**-8.6E+05**	**-56.5%**
HH Respiratory Effects Potential	kg $PM_{2.5}$ eq	5.24E+03	9.34E+03	**-4.1E+03**	**-43.9%**
Eutrophication Potential	kg N eq	4.13E+02	1.61E+03	**-1.2E+03**	**-74.3%**
Ozone Depletion Potential	kg CFC^{-11} eq	1.93E-03	4.32E-03	**-2.4E-03**	**-55.4%**
Smog Potential	kg NOx eq	7.58E+03	1.89E+04	**-1.1E+04**	**-60.0%**

From the comparison of total impact assessment results (Table 4) indicates that, on average, Renovating the BioSciences Building avoids 60% of the potential damages a Newly Built BioSciences

Building would have otherwise created. From this comparison it is also seen that the largest avoided impact are those described by weighted resource use, which indicates that 85% of the disruptions caused to land through resource extraction activities is avoided as a result of renovating rather than building new. Other notable avoided impacts include 2,400 tonnes of CO2 equivalents and 24,000 GJ of fossil fuel consumption.

When considering the impacts assessment results by life cycle stage for both the BioSciences scenarios (Appendix E), an average of 90% of both the Renovating and Building New scenario impacts are being created by the cradle to gate processes responsible for resource extraction and manufacturing of construction products. As these processes were a direct result of the new BioSciences Building designs, these processes were further examined by the building assembly groups they were processing inputs and outputs for. Figure 7 illustrates the distribution of total impact assessment results by assembly group as a direct result of the demands put on the cradle to gate processes by the new BioSciences Building designs in each scenario.

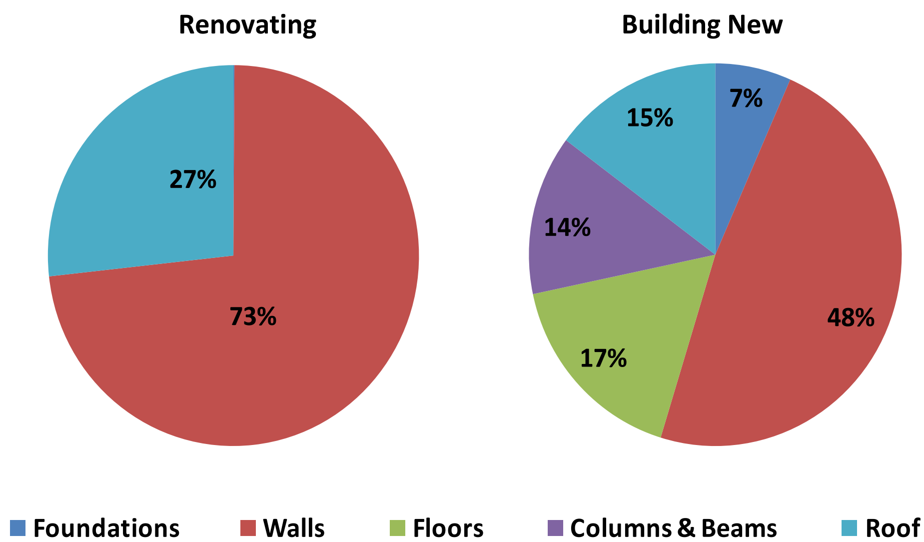

Figure 7 Comparison of average percentage of total impact assessment results for resource extraction, manufacturing and transportation of construction products processes by assembly group for the new BioSciences buildings in the Renovating and Building New scenarios.

As detailed in Figure 7, it is clear that the cradle to gate impacts resulting from the wall assembly designs are a major contributor to the total impact assessment results, as they represent 73% and 48% of the Renovating and Building New scenarios. The primary contributor to this is the need for the reconstruction of all interior walls in the Renovating scenario, and all exterior and interior walls in the Building New scenario. In both cases it can be inferred that the construction product quantities, by weight (Figure 8), and their associated cradle to gate impacts (Figure 7) were greater than those of the other building assembly groups.

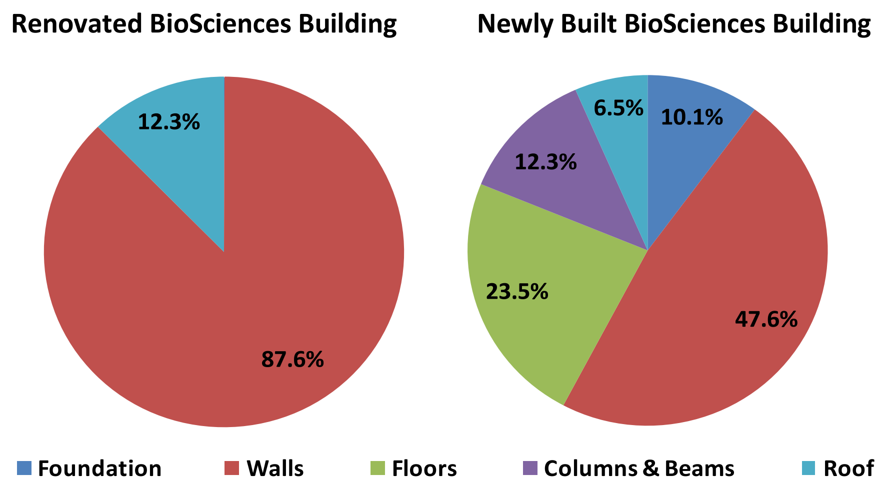

Figure 8 Comparison of contribution from each assembly group to the total results for Bill of Materials, by weight, for the Renovated and Newly Built BioSciences Buildings.

At the building design phase, these results would have been used to inform impact reduction strategies for the design of the walls by indicating where further analysis is required and the impacts of possible design alternatives. When these strategies are applied to the design of an actual building, the outcome is actual environmental impact savings. When applied to hypothetical buildings being used for comparative purposes, the outcome provides insight into the sensitivity of the avoided impact results.

In maintaining focus on the intended purpose of this LCA study, there is little to be gained from investigating the sensitivity of the Renovation scenario as the design of the Renovated BioSciences Building has long been complete and the project is now in the final stages before commissioning. However, as the Newly Built BioSciences Building is a hypothetical formulation being used for comparative purposes, a further investigation of the impacts of the Newly Built BioSciences Building design is carried out in the following section in order to provide insight into the sensitivity of the comparison results.

5.3.1 Sensitivity Analyses

In an LCA study where two products are being compared against one another, the designs and material selections of both products has significant impacts on the comparison results. In this LCA study the comparison carried out involves an actual building design (i.e. Renovated BioSciences Building) and a hypothetical building design (i.e. Newly Built BioSciences Building). As this LCA report is being completed long after the completion of Renovated BioSciences Building design, this sensitivity analysis section first investigates how the comparative results are influenced by Newly Built BioSciences Building's design. This investigation is followed by a second comparison between

the Renovating scenario results and the average cradle to gate impacts of UBC academic buildings in order to test the sensitivity of the results to a different benchmark.

5.3.1.1 Design Decisions in Building New Scenario

There are numerous alterations that could have been made to the Newly Built BioSciences Building design and material specifications. This section first compares the cradle to gate impacts of the Existing BioSciences Building with those of the Renovated BioSciences Building before exploring the sensitivity of design decisions made in the Newly Built BioSciences Building on the Renovation vs. Building New scenario comparison.

As the Newly Built BioSciences Building design was derived from a few alterations to the Existing BioSciences Building design, a pre-design alteration benchmark is established through a comparison of the initial construction of the Existing BioSciences Building and the Renovation scenario (Table 5). In this comparison, it is important to consider that the Existing BioSciences Building is assumed to be constructed in 2011 using current technologies as there is no life cycle inventory or impact assessment information available from its actual construction between 1957 and 1970.

Table 5 Comparison of Renovating Scenario and Existing BioSciences Building total cradle to gate impact assessment results.

Impact Category	Category Indicator	Scenario Total Impact Assessment Results		Difference	
		Renovating	Existing	Absolute	Percent
Fossil Fuel Consumption	MJ	2.45E+07	3.39E+07	**-9.38E+06**	**-27.6%**
Weighted Resource Use	kg	2.70E+06	1.77E+07	**-1.50E+07**	**-84.7%**
Global Warming Potential	kg CO2 eq	1.43E+06	3.01E+06	**-1.58E+06**	**-52.6%**
Acidification Potential	moles of H+ eq	6.67E+05	1.36E+06	**-6.93E+05**	**-51.0%**
HH Respiratory Effects Potential	kg PM2.5 eq	5.24E+03	9.55E+03	**-4.32E+03**	**-45.2%**
Eutrophication Potential	kg N eq	4.13E+02	1.48E+03	**-1.07E+03**	**-72.1%**
Ozone Depletion Potential	kg CFC-11 eq	1.93E-03	4.11E-03	**-2.18E-03**	**-53.0%**
Smog Potential	kg NOx eq	7.58E+03	1.68E+04	**-9.25E+03**	**-54.9%**

With an average of 55% avoided in each category, this comparison illustrates very similar proportions of avoided impacts to those of the Newly Built vs. Renovation Scenario, which had an average of 60% avoided impacts. The most notable differences in avoided impacts between these two comparisons

is that less fossil fuel consumption (20%) and global warming potential (10%) are avoided in the Renovation vs. Existing comparison, which is likely primarily due to avoiding the end of life impacts associated with demolishing an existing building.

In order to test the sensitivity of the Building New scenario as well as its comparison with the Renovating scenario, two decisions with respect to the Newly Built BioSciences Building's design are investigated. As the wall assemblies in the Newly Built BioSciences Building are the main contributor to the Building New scenario impact assessment results (Figure 7), two wall assembly design decisions are focused on. These include the decision to:

- maintain the wall type mix from the Existing BioSciences Building, and
- increase in floor to floor height.

The Newly Built BioSciences Building inherited a mix of interior walls from the Existing Building design that entailed, as a percentage of total linear feet of interior walls, roughly 65% steel studs and 30% concrete block. The decision to maintain this mix, instead of replacing the concrete block walls with steel studs, contributed an average of 9% across all impact categories to the Building New scenario total impact assessment results (Table 6).

The floor to floor height of the Existing BioSciences Building was 3.2m, which was increased to 4m in the Newly Built BioSciences Building design to reflect likely updates that would have occurred in its design. It is important to consider that the inherited mix of interior walls described above was maintained in this increase and that this floor height increase also affected the design of the supporting columns. The design decision to increase the floor to floor height contributed an average of 4% across all impact categories to the Building New total impact assessment results (Table 6).

The maintenance of concrete block walls and increased floor to floor heights were incorporated into an alternative design that was incorporated into an Alternative Building New scenario and subsequently compared with the Renovating scenario in order to gain insight into their impact on the comparison results. Table 7 provides the details of the Alternative Building New scenario comparison with the Renovating scenario, where the Newly Built BioSciences building replaces the 30% concrete block wall usage with steel stud walls and the floor to floor height is maintained at 3.2m.

Table 6 Contribution of concrete block wall use and increased wall height to total impact assessment result for Building New scenario.

Impact Category	Category Indicator	Scenario Total Impact Assessment Result	Margin of Impact Assessment Result Increase due to Design Decision			
			30% Concrete Wall instead of Steel Stud		4.0m Wall Height instead of 2.9m	
		Building New	Difference	Percentage of Building New Scenario Total	Difference	Percentage of Building New Scenario Total
Fossil Fuel Consumption	MJ	4.85E+07	3.01E+06	6.2%	1.62E+06	3.3%
Weighted Resource Use	kg	1.80E+07	1.30E+06	7.2%	7.07E+05	3.9%
Global Warming Potential	kg CO_2 eq	3.78E+06	3.24E+05	8.6%	1.38E+05	3.7%
Acidification Potential	moles of H^+ eq	1.53E+06	1.39E+05	9.1%	7.20E+04	4.7%
HH Respiratory Effects Potential	kg $PM_{2.5}$ eq	9.34E+03	8.79E+02	9.4%	5.20E+02	5.6%
Eutrophication Potential	kg N eq	1.61E+03	1.72E+02	10.7%	8.58E+01	5.3%
Ozone Depletion Potential	kg CFC^{-11} eq	4.32E-03	5.58E-04	12.9%	1.89E-04	4.4%
Smog Potential	kg NOx eq	1.89E+04	1.71E+03	9.1%	7.26E+02	3.8%

Table 7 Comparison of Renovating and Alternative Building New Scenarios total impact assessment results.

Impact Category	Category Indicator	Scenario Total Impact Assessment Results		Difference	
		Renovating	Alternative Building New	Absolute	Percent
Fossil Fuel Consumption	MJ	2.45E+07	4.39E+07	**-1.93E+07**	**-44.0%**
Weighted Resource Use	kg	2.70E+06	1.60E+07	**-1.33E+07**	**-83.2%**
Global Warming Potential	kg CO_2 eq	1.43E+06	3.32E+06	**-1.89E+06**	**-57.0%**
Acidification Potential	moles of H^+ eq	6.67E+05	1.32E+06	**-6.53E+05**	**-49.5%**
HH Respiratory Effects Potential	kg $PM_{2.5}$ eq	5.24E+03	7.95E+03	**-2.71E+03**	**-34.1%**
Eutrophication Potential	kg N eq	4.13E+02	1.35E+03	**-9.39E+02**	**-69.4%**
Ozone Depletion Potential	kg CFC^{-11} eq	1.93E-03	3.57E-03	**-1.65E-03**	**-46.0%**
Smog Potential	kg NOx eq	7.58E+03	1.65E+04	**-8.91E+03**	**-54.0%**

As a result of the alterations in the Newly Built BioSciences design discussed above, the average avoided impacts have reduced from the initial 60% to 55%. That is, the reduced impact assessment results of the Alternative Newly Built BioSciences design have in turn reduced the overall Renovating scenarios avoided impacts by 5%. These avoided impact reductions ranged from as little as 2% in weighted resource use to as much as 10% in human health respiratory effects potential. This reduced comparison result demonstrates the sensitivity avoided impact estimates to the scenarios they are based on, as well as the direct influence of building design decisions to environmental impacts created.

With these demonstrated points in mind, the importance of a having robustly developed scenarios should be highlighted. That is, the Renovating scenario results are quite robust relative to those of the Building New scenario because the Renovated BioSciences Building model is based on actual building designs and the Newly Built BioSciences Building model is based on hypothetical designs. Thus, in order to ensure that the intended purpose of this study is achieved (i.e. communicate the benefits of renovating rather than building new), it seems appropriate to consider a further comparisons the Renovating scenario results using a more robust benchmark. The following section provides the details of a second comparison with the results of a UBC academic building cradle to gate impact average that has been developed from models based on actual building designs.

5.3.1.2 Benchmarking Material Impacts against UBC Academic Building Average

This section provides the details of a secondary comparison made between the Renovating scenario and the cradle to gate UBC Vancouver campus average academic building impact assessment results. This UBC average is based on a sample of 29 cradle to gate (i.e. resource extraction to construction of building) LCA studies on the material impacts of UBC academic buildings. These studies have been aggregated into a database, known as the UBC LCA Database, which is considered North America's largest regional building LCA database. The studies included in the UBC LCA Database have been carried out between 2009 and 2011 by students taking CIVL 498C – Whole Building Life Cycle Assessment, and are part of the UBC Social, Ecological, Economic, Directed Studies (SEEDS) program, which has the studies publicly available in their project library[14].

The UBC LCA Database currently estimates the impacts associated with resource extraction, manufacturing of structural and envelope construction products, the construction activity required to assemble these products into a building, as well as all related transportation effects occurring within this cradle to gate system boundary. The average impact assessment results calculated from the building LCA studies in the UBC LCA Database are considered highly representative of the material impacts of constructing new academic buildings at the UBC Vancouver campus. This assertion is founded in the large sample size of buildings it includes and the fact that each has been developed directly from the actual building design drawings. The sample size of buildings included in the preliminary release of the UBC LCA Database (version 1.0) is just over 50% of the square footage of

[14] UBC SEEDS Project Library – http://www.sustain.ubc.ca/seeds-library

the total academic building square footage that has been constructed at the UBC Vancouver campus in all years prior to 2011. In addition to this, these LCA studies were carried out in a similar manner as the BioSciences LCA study. That is, they use a similar Goal & Scope, modeling methods (i.e. developed from original as-built architectural and structural drawings and site visits) and tools (i.e. the Impact Estimator). Due to its representativeness and similarities between the development of the studies it contains with the BioSciences study, the UBC LCA Database results are considered highly suitable for comparison with those of the Renovating scenario LCA results.

However, two discrepancies should be considered before continuing with the comparison. The first is that none of the original constructions of the academic buildings in the UBC LCA Database were as a result of the renovation or demolition of an existing building. Secondly, the designs and materials used in the structures and envelopes of the academic buildings in the UBC LCA Database vary significantly. The outcomes of these discrepancies are that the result of the ensuing comparisons will be considered a renovation versus new construction without the need for demolition of an existing structure and they will also place the Renovating scenario results within the context of cradle to gate impacts of academic buildings on the UBC Vancouver campus.

In order to render a comparison between the Renovating scenario and the averaged UBC academic building impact assessment results, the impact assessment results were divided by the total square footage of both Renovated New BioSciences Building wings – ie. 131,890 ft^2. This step was required due to the variance in building square footage of academic buildings at UBC. The result is that the impact assessment results are expressed in *per square foot post-secondary academic building constructed* functional units, which enables the impact assessment results to be compared on an equal footing (Table 8).

Table 8 Comparison of Renovating scenario with averaged UBC academic building impact assessment results.

Impact Category	Category Indicator	Total Impact Assessment Results *per square foot post-secondary academic building constructed*		Difference	
		Renovating Scenario	UBC Academic Building Average	Absolute	Percent from UBC Academic Building Average
Fossil Fuel Consumption	MJ	1.86E+02	2.91E+02	**-1.05E+02**	**-36%**
Weighted Resource Use	kg	2.05E+01	1.62E+02	**-1.42E+02**	**-87%**
Global Warming Potential	kg CO_2 eq	1.08E+01	2.44E+01	**-1.36E+01**	**-56%**
Acidification Potential	moles of H^+ eq	5.06E+00	1.01E+01	**-5.04E+00**	**-50%**
HH Respiratory Effects Potential	kg $PM_{2.5}$ eq	3.97E-02	8.06E-02	**-4.09E-02**	**-51%**
Eutrophication Potential	kg N eq	3.13E-03	1.01E-02	**-6.97E-03**	**-69%**
Ozone Depletion Potential	kg CFC^{-11} eq	1.46E-08	5.48E-08	**-4.02E-08**	**-73%**
Smog Potential	kg NOx eq	5.75E-02	1.19E-01	**-6.15E-02**	**-52%**

The percent difference results shown in Table 8 indicate that the impact of the decision to construct a New BioSciences Building by renovating has resulted in an impact assessment result per square foot constructed that is on average 59% lower than the average UBC academic building construction impact. Individual results within the impact categories investigated range from the Renovating scenario having 36% lower fossil fuel consumption to 87% lower weighted resource use when compared to the UBC academic average.

A primary outcome of this comparison is the clearly indication that renovating can also avoid more impacts than construction without the need to demolish an existing structure. When comparing these results with the Renovating and Building New scenarios, we see that the overall average avoided impacts are approximately the same. This is a very interesting result that further highlights the benefits of avoiding impacts by salvaging existing structures, as approximately 90% of all impacts of the buildings in these comparisons are born in the resource extraction and manufacturing of new construction materials. Furthermore, weighted resource use is the largest avoided impact in both comparisons, which indicates that the largest avoided impact is the reduction in need for resource extraction activities that disrupt land areas.

In order to provide further context from this comparison, the overall percent difference of the Renovating scenario impact assessment results have been benchmarked alongside all of the individual academic buildings in version 1.0 of the UBC LCA Database (Figure 9).

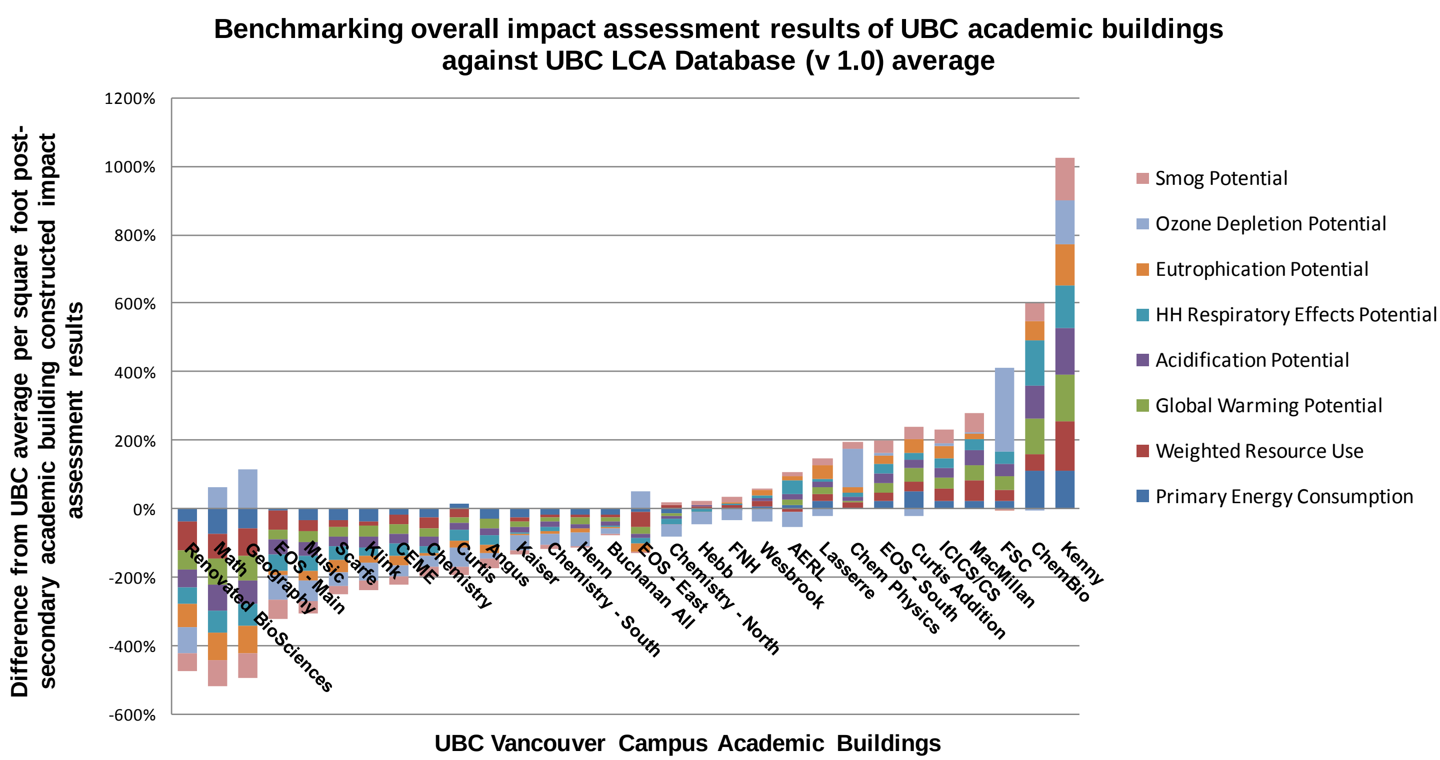

Figure 9 Renovating scenario benchmarked alongside UBC academic buildings against the UBC average per square foot post-secondary academic building constructed impact assessment result.

This benchmarking indicates that the Renovated BioSciences Building (produced by the Renovating scenario) has the lowest overall impact, relative to the average academic building average, among all thirty benchmarked UBC academic buildings. Figure 9 also identifies the Renovated BioSciences Building as having the lowest material impacts among the four buildings constructed to Leadership in Energy and Environmental Design (LEED) standards included in the benchmarking. The other three benchmarked LEED buildings include the Kaiser, Aquatics Ecosystem Research Laboratory (AERL), Chemical & Biological Engineering (ChemBio) buildings.

As a result of the Renovating scenarios secondary comparison with the UBC academic building average two new observations were made. The first is that regardless of whether an existing structure requires demolition first, renovating and academic building rather than building new creates a significant opportunity to avoid environmental impacts due to avoiding the need to create new construction products. Secondly, the Renovated BioSciences scenario demonstrated a superior cradle to gate environmental performance to all other UBC academic buildings, including those built to LEED standards. These observations indicate that UBC should continue upgrading existing buildings as an effective strategy to avoiding environmental impacts.

5.3.2 Weighting Avoided Inventory and Impact

An additional request was put forth by the party commissioning this LCA study, UBC Project Services, to provide a 'cost avoidance statement' to use in the interpretation of this study's resource use inventory analysis and impact assessment results. This request took on the form of a weighting exercise that was carried out on those impacts avoided as a result of UBC Project Service's decision to pursue the Renovation scenario rather than the Built New scenario. The following is a summary of the major findings of this weighting exercise.

For the avoided inventory analysis results, weighting the entire bill of resources consumed was not feasible. Thus, only fuel and water inventory analysis results were included in the weighting exercise, which included specifically coal, natural gas, crude oil (assumed as gasoline) and water. The avoided costs associated with these inventories were estimated based on current market prices in the Vancouver metro region. Avoiding the use of these resources saved an estimated $255,000, of which 6% or $15,000 was avoided BC carbon taxation.

The weighting of avoided impact assessment results included global warming, eutrophication, acidification, human health respiratory effects and smog potential impact categories. The avoided costs associated with these impact categories were calculated using market prices for impact abatement and loss of productivity in the case of health effects. Overall, it was found that the avoided impact assessment results were approximately $140,000 in environmental and human health costs as a result of renovating the BioSciences building rather than building new.

It is recommended that the reader consult the full details of the methodology, data sources and assumptions included in the weighting exercise included in Appendix F in order to properly interpret the results summarized above. Furthermore, in accordance with ISO 14044, the figures used in this weighting exercise are available in sections 5.2 and 5.3 of this report.

6. Conclusions

The primary intended application of this LCA study is to provide a transparent marketing tool to communicate the benefits of renovating the Existing BioSciences Building rather than completely demolishing it and constructing a completely new BioSciences Building. In order to achieve this outcome, two scenarios were developed, Renovating and Building New, through detailed Goal & Scope document in accordance with ISO 14040 and 14044. The parameters defined in the Goal & Scope document guided the development of two LCA models, which produced inventory analysis and impact assessment results to describe the environmental merits of the Renovating and Building New scenarios through comparative analysis.

In the development of this LCA study, a significant amount of effort was placed on producing a complete and transparent study that can be understood and reproduced, as its secondary intended application is as an asset to furthering development of LCA into sustainability in building construction. The primary outcomes of this effort are the Inputs and Assumptions Documents which provide full disclosure of the modeling inputs and assumptions required to produce LCA results using the Impact Estimator software.

The most notable avoided inventory analysis results from the comparison of the Renovating and Building New scenarios are the following;

- 4 million L of water
- 16 tonnes of coal
- 280,000 m^3 of natural gas
- 120,000 L of crude oil

In the second comparison of impact assessment results, it was found that the overall benefit of renovating rather than building new was an average of 60% avoided impact among categories investigated. Figure 10 illustrates the proportions of each impact category that were avoided as a result of renovating the BioSciences building rather than building new.

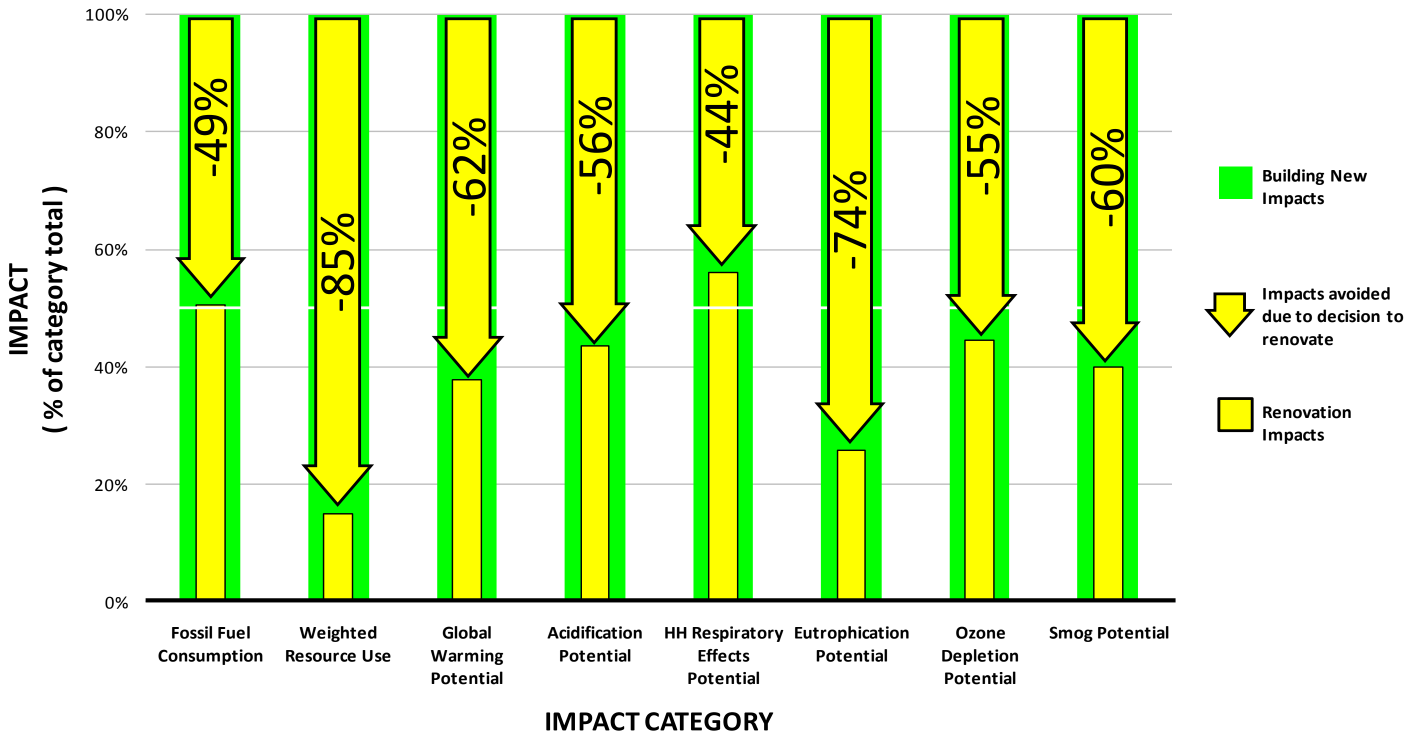

Figure 10 Impacts avoided due to decision to renovate the BioSciences building rather than building new.

The details of these avoided impacts are as follows;

- 49% (24,000,000 MJ) less fossil fuels consumed,
- 85% (15,000,000 ecologically weighted kg) less weighted resource use impacts,
- 62% (2,400,000 kg CO_2 equivalents) less global warming substances emitted,
- 57% (860,000 moles H^+ equivalents) less acidifying substances emitted,
- 44% (4,100 kg $PM_{2.5}$equivalents) less human health respiratory system impacting substances emitted,
- 74% (1,200 kg N equivalents) less eutrophying substances emitted,
- 55% (0.0024 kg CFC^{-11} equivalents) less ozone layer depleting substances emitted, and lastly
- 60% (11,000 kg NOx equivalents) less smog forming emission emitted.

It was found that among impact categories, an average of 90% of the impact assessment results were being created by the resource extraction and manufacturing of new construction products, with the wall assemblies being responsible for a an average of 73% of the Renovating scenario results and 48% of the Building New scenario.

Two sensitivity analyses were completed on the impact assessment results.

The first included an analysis into the wall impacts resulted in the formulation of an Alternative Building New scenario, which incorporated a change in wall type from concrete block to steel stud and a decrease in floor to floor height from 4.0m to 3.2m. The result of this comparison was a 5% average reduction in avoided impacts for the Renovating scenario, with the least sensitivity being

seen in weighted resource use (2% reduction) and the largest change being seen in human health respiratory effects potential (10% reduction).

After demonstrating the sensitivity to the benchmark being compared against, a second sensitivity analysis was undertaken where the Renovating scenario was compared against the UBC academic building average on a *per square foot post secondary institution* basis. A primary outcome of this scenario was demonstrating that the Renovating scenario could outperform new construction even when there is no need to demolish an existing structure, as it avoided an average of 59% among impact assessment results. Figure 11 illustrates the proportions of avoided impacts as a result of this comparison.

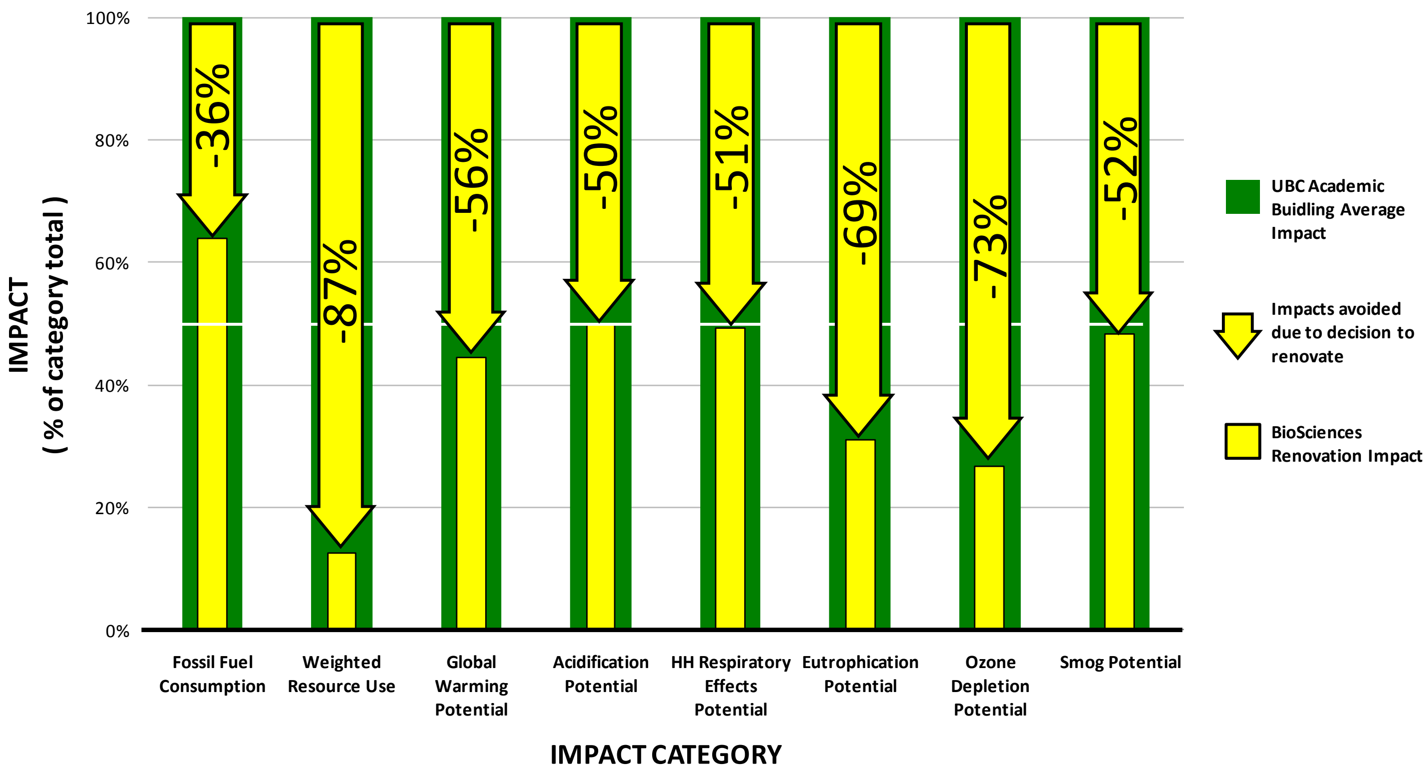

Figure 11 Impacts avoided due to decision to renovate the BioSciences building relative to the average impact of constructing a new UBC academic building.

The details of these avoided impacts are as follows;

- 56% (105 MJ) less fossil fuels are consumed,
- 87% (142 ecologically weighted kg) less weighted resource use impacts,
- 56% (14 kg CO_2 equivalents) less global warming substances are emitted,
- 50% (5 moles H+ equivalents) less acidifying substances are emitted,
- 51% (0.04 kg $PM_{2.5}$equivalents) less human health respiratory system impacting substances are emitted,
- 69% (0.01 kg N equivalents) less eutrophying substances are emitted,
- 73% (4.0x10-8 kg CFC^{-11} equivalents) less ozone layer depleting substances are emitted, lastly
- 52% (0.06 kg NOx equivalents) less smog forming emission are emitted.

The secondary outcome of this comparison was indicating that the Renovating scenario has the lowest cradle to gate impacts amongst thirty UBC academic buildings, and the lowest among the four constructed to LEED standards, in terms of cumulative impact relative to the UBC academic average.

This report provides a transparent and conclusive account of the environmental benefits created by UBC Project Services decision to upgrade the existing BioSciences building by renovating rather than building new with and without demolition of an existing building.

7. Recommendations

It is recommended that Project Services continue requesting the completion of LCAs on their Renew Projects and continue marketing the clear environmental benefits of their efforts to renovate UBC buildings rather than demolish and build new.

To improve the benefits of this effort, it is recommended that LCA be incorporated earlier in the design process of the Renew Projects. This would create an opportunity to compare and contrast the merits of renovation designs based on their potential to reduce the overall environmental impact of the project. Thus, the primary recommendation from this LCA study is to involve LCA earlier in the project. This would enable assumptions regarding the sustainability of design decisions to be tested in order to optimize the overall building design against environmental performance targets, which would in turn be able to be reported on.

Integrating LCA earlier in a project also increases the potential to increase the accuracy of the study as there is greater opportunity to gain input from relevant contractors and consultants as well as strategize empirical data collection. For instance, the short turnaround on this LCA study meant that the end of life processes for construction and demolition wastes were not included, which could affect the accuracy of estimate the total impact of the studied scenarios. Strategizing the incorporation of end of life processes for wastes into the system boundary would likely increase the amount of materials being diverted into subsequent life cycles, where those lowest impacts would be incentivized.

Lastly, it is recommended that Project Services develop standardized Goal & Scope and Interpretations guidelines to be followed by future LCAs conducted on their projects. These standardized guidelines would enable Project Services to regulate the quality of the LCA studies they request and build a repository of historical LCA studies all carried out to the same standard. This would help Project Services build a valuable information assets which can be used to track their progress towards environmental performance targets and also contribute to the development of sophisticated strategies to optimize their efforts. There has already been some progress made on this recommendation through the UBC LCA Database (cited in the Interpretation section) and it is recommended that Project Services incorporate those LCA assets already built through this effort as it will provide a significant starting point in accelerating the development of LCA into sustainable construction practices at UBC.

Appendix A Impact Category Definitions

The following are the descriptions of the eight environmental measures used to summarize the environmental assessment results provided by the Impact Estimator version 4.1.13.

Fossil Fuel Consumption

Fossil Fuel Consumption is reported in mega-joules (MJ). Embodied Fossil Fuel Consumption includes all energy, direct and indirect, used to transform or transport raw materials into products and buildings, including inherent energy contained in raw or feedstock materials that are also used as common energy sources. (For example, natural gas used as a raw material in the production of various plastic (polymer) resins.) In addition, the Impact Estimator captures the indirect energy use associated with processing, transporting, converting and delivering fuel and energy plus the operating energy.

Acidification Potential (AP)

Acidification is a more regional rather than global impact effecting human health when high concentrations of NO_x and SO_2 are attained. The AP of an air or water emission is calculated on the basis of its H^+ equivalence effect on a mass basis.

Aquatic Eutrophication Potential

Eutrophication is the fertilization of surface waters by nutrients that were previously scarce. When a previously scarce or limiting nutrient is added to a water body it leads to the proliferation of aquatic photosynthetic plant life. This may lead to a chain of further consequences ranging from foul odours to the death of fish. The calculated result is expressed on an equivalent mass of nitrogen (N) basis.

Global Warming Potential (GWP)

Global warming potential is a reference measure. The methodology and science behind the GWP calculation can be considered one of the most accepted LCIA categories. GWP will be expressed on an equivalency basis relative to CO_2 – in kg or tonnes CO_2 equivalent.

Carbon dioxide is the common reference standard for global warming or greenhouse gas effects. All other greenhouse gases are referred to as having a "CO_2 equivalence effect" which is simply a multiple of the greenhouse potential (heat trapping capability) of carbon dioxide. This effect has a time horizon due to the atmospheric reactivity or stability of the various contributing gases over time.

As yet, no consensus has been reached among policy makers about the most appropriate time horizon for greenhouse gas calculations. The International Panel on Climate Change100-year time horizon figures have been used here as a basis for the equivalence index:

CO_2 Equivalent kg = CO_2 kg + (CH_4 kg x 23) + (N_2O kg x 300)

While greenhouse gas emissions are largely a function of energy combustion, some products also emit greenhouse gases during the processing of raw materials. Process emissions often go unaccounted for due to the complexity associated with modeling manufacturing process stages. One example where process CO_2 emissions are significant is in the production of cement (calcination of limestone). Because the Impact Estimator uses data developed by a detailed life cycle modeling approach, all relevant process emissions of greenhouse gases are included in the resultant global warming potential index.

Human Health (HH) Criteria Air-Mobile

Particulate matter of various sizes (PM_{10} and $PM_{2.5}$) have a considerable impact on human health. The EPA has identified "particulates" (from diesel fuel combustion) as the number one cause of human health deterioration due to its impact on the human respiratory system – asthma, bronchitis, acute pulmonary disease, etc. It should be mentioned that particulates are an important environmental output of plywood product production and need to be traced and addressed. The Institute used TRACI's "Human Health Particulates from Mobile Sources" characterization factor, on an equivalent $PM_{2.5}$ basis, in our final set of impact indicators.

Ozone Depletion Potential (ODP)

Stratospheric ozone depletion potential accounts for impacts related to the reduction of the protective ozone layer within the stratosphere caused by emissions of ozone depleting substances (CFCs, HFCs, and halons). The ozone depletion potential of each of the contributing substances is characterized relative to CFC-11, with the final impact indicator indicating mass (e.g., kg) of equivalent CFC-11.

Weighted Resource Use

Weighted resource use can be measured in common units such as tonnes, but a unit of one resource like iron ore is not at all comparable to a unit of another resource like timber or coal when it comes to environmental implications of extracting resources. Since the varied effects of resource extraction, (e.g., effects on bio-diversity, ground water quality and wildlife habitat, etc.) are a primary concern, we want to make sure they are taken into account. The problem is that while these ecological carrying capacity effects are as important as the basic life cycle inventory data, they are much harder to incorporate for a number of reasons, especially their highly site-specific nature.

Our approach was to survey a number of resource extraction and environmental specialists across Canada to develop subjective scores of the relative effects of different resource extraction activities. The scores reflect the expert panel ranking of the effects of extraction activities relative to each other

for each of several impact dimensions. The scores were combined into a set of resource-specific index numbers, which are applied in the Impact Estimator as weights to the amounts of raw resources used to manufacture each building product. The Weighted Resource Use values reported by the Impact Estimator are the sum of the weighted resource requirements for all products used in each of the designs. They can be thought of as "ecologically weighted kilograms", where the weights reflect expert opinion about the relative ecological carrying capacity effects of extracting resources. Excluded from this measure are energy feedstocks used as raw materials. Except for coal, no scoring survey has been conducted on the effects of extracting fossil fuels, and hence, they have been assigned a score of one to only account for their mass. The weighting factor for each raw material is set out below:

Weighted Resource Use is the same as normal resource converted to mass quantities for all resources with the exception of limestone, iron ore, coal and wood fiber. The weighted resource use characterization factors for these exceptions are:

- 1.5 for Limestone
- 2.25 for Iron Ore
- 2.25 for Coal
- 2.5 for Wood Fiber

Photochemical Ozone Formation Potential (Smog)

Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level where, in the presence of sunlight, they produce photochemical smog, a symptom of photochemical ozone creation potential (POCP). While ozone is not emitted directly, it is a product of interactions of volatile organic compounds (VOCs) and nitrogen oxides (NOx). The “smog” indicator is expressed on a mass of equivalent NOx basis.

Appendix B Input Documents

This Appendix contains all of the building information input into the Impact Estimator for each of the processes modeled. The Known/Measured column indicates what was known and/and measured about the associated input field for each given assembly. Where a dash " – " is seen in this column indicates that an assumption was required, and the reader should consult the Assumptions Document that complements the Input document being read.

Table 9 Partial Demolition of Existing BioSciences Building Inputs Document.

Partial Demolition of Existing BioSciences Building Inputs Document					
				Input Values	
Assembly Group	Assembly Type	Assembly Name (**S**:South Wing **W**:West Wing)	Input Fields	Known/ Measured	IE Inputs
1.) Walls	1.1 Concrete Block Wall				
		1.1.1 S_Concrete BlockWall_SubBasement			
		Door Opening	Length (ft)	246	246
			Height (ft)	9.66	9.66
			Rebar	-	#4
			Number of Doors	7	7
			Door Type	Steel Interior	Steel Interior
		1.1.2 S_Concrete BlockWall_Roof			
		Door Opening	Length (ft)	328	328
			Height (ft)	7	7
			Rebar	-	#4
			Number of Doors	4	4
			Door Type	Steel Exterior	Steel Exterior
		1.1.3 S_Concrete BlockWall_Interior			
		Door Opening	Length (ft)	2788	2788
			Height (ft)	12.5	12.5
			Rebar	-	#4
			Number of Doors	81	81
			Door Type	Solid Wood	Solid Wood
		1.1.4 W_Concrete BlockWall_0000			
		Door Opening	Length (ft)	109	109
			Height (ft)	15.75	15.75
			Rebar	-	#4
			Number of Doors	3	3
			Door Type	Steel Interior	Steel Interior
		1.1.5 W_Concrete BlockWall_Interior_1000/2000/3000			
		Door Opening	Length (ft)	510	510
			Height (ft)	12.5	12.5
			Rebar	-	#4
			Number of Doors	8	8
			Door Type	Solid Wood	Solid Wood
	1.2 Steel Stud				
		1.2.1 S_SteelStud_ServiceStrip			

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Length (ft)	1790	1790
			Height (ft)	12.5	12.5
			Sheathing	Plywood	Plywood
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	112	112
			Total Window Area(ft2)	6484	6484
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Door Opening	Number of Doors	4	4
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	1
		1.2.2 W_SteelStud_Interior_1000/2000/3000			
			Length (ft)	561	5612
			Height (ft)	12.5	12.5
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Door Opening	Number of Doors	133	133
			Door Type	Solid Wood	Solid Wood
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Moisture
			Thickness (in)	-	5/8"
		1.2.3 W_SteelStud_Exterior_1000/2000/3000			
			Length (ft)	892	892
			Height (ft)	12.5	12.5
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Heavy Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	68	68

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Total Window Area(ft2)	398	398
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Reg
			Thickness (in)	-	5/8"
		Envelope	Category	Insulation	Insulation
			Material	Fiberglass Batt	Fiberglass Batt
			Thickness (in)	-	2"
		1.2.4 W_SteelStud_WindowWall_5000			
			Length (ft)	272	272
			Height (ft)	5.4	5.4
			Sheathing	Plywood	Plywood
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	17	17
			Total Window Area(ft2)	1101	1101
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Moisture
			Thickness (in)	-	5/8"
		Envelope	Category	Cladding	Cladding
			Material	Ceramic Tiles	Brick Spilt Faced
			Thickness	-	-
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
		1.2.4 W_SteelStud_ExteriorDoorWall_5000			
			Length (ft)	24	24

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	Input Values IE Inputs
			Height (ft)	7	7
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Door Opening	Number of Doors	8	8
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		1.2.5 W_SteelStud_DoorWallReno_0000			
			Length (ft)	16	16
			Height (ft)	7	7
			Sheathing	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	-	39 x 92
		Door Opening	Number of Doors	5	5
			Door Type	Steel Interior	Steel Interior
	1.3 Wood Stud				
		1.3.1 S_WoodStud_Pipe/DuctSpace			
			Length (ft)	523	523
			Height (ft)	12.5	12.5
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Kiln Dried
			Stud Thickness	-	2x4
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Reg
			Thickness (in)	-	5/8"
		1.3.1 W_WoodStud_PartitionWall_1000			
			Length (ft)	92	92
			Height (ft)	7	7
			Sheathing	None	None
			Stud Spacing	-	24 o.c.
			Stud Weight	-	Kiln Dried
			Stud Thickness	-	2x3
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Reg
			Thickness (in)	-	1/2"
	1.4 Concrete Tilt Up				

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
		1.4.1 W_Concrete_TiltUp_Exterior_2000/3000			
			Length (ft)	188	125
			Height (ft)	12.5	12.5
			Thickness (in)	4	6
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		Envelope	Category	Cladding	Cladding
			Material	Stucco	Stucco (over porous surface)
			Thickness (in)	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
		1.4.2 W_Concrete_TiltUp_Exterior_4000			
			Length (ft)	93	62
			Height (ft)	5	5
			Thickness (in)	4	6
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		Envelope	Category	Cladding	Cladding
			Material	Stucco	Stucco (over porous surface)
			Thickness (in)	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
	1.5 Curtain Wall				
		1.5.1 W_CurtainWall_2000/3000			
			Length (ft)	228	228
			Height (ft)	12.5	12.5
			Viewable Glazing (%)	38	38
			Spandrel Panel (%)	62	62
			Insulation Thickness (in)	2	2
			Spandrel Panel Type	Opaque Glass	Opaque Glass
		1.5.2 W_CurtainWall_4000			

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Length (ft)	114	114
			Height (ft)	5	5
			Viewable Glazing (%)	0	0
			Spandrel Panel (%)	100	100
			Insulation Thickness (in)	2	2
			Spandrel Panel Type	Opaque Glass	Opaque Glass
2.) Extra Basic Materials	2.1 Roofing Materials				
			#15 Organic Felt (100sf)	4,850.94	4,850.94
			Ballast (lbs)	1,426,806.75	1,426,806.75
			Extruded Polystyrene (sf, 1"thick)	111,780.52	111,780.52
			Galvanized Sheet (tons)	3.25	3.25
			Polyethylene Filter Fabric (tons)	0.79	0.79
			Roofing Asphalt (lbs)	100,847.20	100,847.20
	2.2 Back Out				
			Galvanized Studs (Tons)	-0.04	-0.04
			Screws Nut& Bolts (Tons)	-0.00	-0.00
	2.3 Cladding				
			Split Face Brick (Blocks)	15,246.00	15,246.00
	2.4 Polyethylene				
			Polyethylene 6mil (m2)	5,125.00	5,125.00

Table 10 Partial Construction of New BioSciences Building Inputs Document.

Partial Construction of New BioSciences Building Inputs Document

Assembly Group	Assembly Type	Assembly Name (**S**:South Wing **W**:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
1.) Walls	1.1 Concrete Cast in Place				
		1.1.1 S_Concrete_Cast-in-Place_SesmicWall_1000/2000/3000/4000			
			Length (m)	137	137
			Height (m)	3.81	3.81
			Thickness (mm)	200	200
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	15M	15M
		1.1.2 S_Concrete_Cast-in-Place_SesmicWall_0000			
			Length (m)	36	36
			Height (m)	3.5	3.5
			Thickness (mm)	200	200
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	15M	15M
		1.1.3 W_Concrete_Cast-in-Place_SesmicWall_1000/2000/3000/5000			
			Length (m)	216	216
			Height (m)	3.81	3.81
			Thickness (mm)	300	300
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	15M	15M
		1.1.4 W_Concrete_Cast-in-Place_SesmicWall_4000			
			Length (m)	48	48
			Height (m)	0.7	0.7
			Thickness (mm)	300	300
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	15M	15M
		1.1.5 W_Concrete_Cast-in-Place_SesmicWall_0000			
			Length (m)	47	47
			Height (m)	4.7	4.7
			Thickness (mm)	300	300

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	IE Inputs
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	15M	15M
		1.1.6 S_Concrete_Cast-in-Place_Tanks			
			Length (m)	32	32
			Height (m)	2	2
			Thickness (mm)	200	200
			Concrete (MPa)	-	30
			Concrete flyash %	-	average
			Rebar	15M	15M
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
	1.2 Concrete Block Wall				
		1.2.1 S_Concrete_BlockWall_P18/P28			
			Length (m)	49	49
			Height (m)	3.5	3.5
			Rebar	-	10M
			Number of Doors	7	7
			Door Type	Steel Interior	Steel Interior
		1.2.2 W_Concrete_BlockWall_P28			
			Length (m)	25	25
			Height (m)	4.6	4.6
			Rebar	-	10M
			Number of Doors	2	2
			Door Type	Steel Interior	Steel Interior
	1.3 Steel Stud				
		1.3.1 SteelStud_P4/P6/P7/P8/P21/P23/P24/P25			
			Length (m)	2081	2081
			Height (m)	2.9	2.9
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 92	39 x 92
		Door Opening	Number of Doors	176	176
			Door Type	Steel Interior	Steel Interior
		Envelope	Category	Insulation	Insulation

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	Input Values IE Inputs
		Envelope	Material	Mineral Wool Batt	Rockwool Batt
			Thickness (mm)	92	92
			Category	Gypsum	Gypsum
			Material	Type "x" GWB	Gypsum Regular
			Thickness (mm)	5/8"	5/8"
		1.3.2 W_SteelStud_WindowFrameWall_1000			
		Window	Length (m)	165	165
			Height (m)	0.56	0.56
			Sheathing	None	None
			Stud Spacing	-	600 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	-	39 x 92
			Number of Windows	37	37
			Total Window Area(m2)	76	76
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	Argon Filled	Tin Argon Filled
		1.3.3 SteelStud_DoorWallReno			
		Door Opening	Length (m)	41	41
			Height (m)	2.19	2.19
			Sheathing	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	-	39 x 92
			Number of Doors	45	45
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		1.3.4 W_SteelStud_DoorWallReno_0000			
		Door Opening	Length (m)	4	4
			Height (m)	2.19	2.19
			Sheathing	None	None
			Stud Spacing	-	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	-	39 x 92
			Number of Doors	5	5
			Door Type	Steel Interior	Steel Interior

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	Input Values IE Inputs
		1.3.5 SteelStud_P3/P5/P16			
			Length (m)	520	520
			Height (m)	2.9	2.9
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 152	39 x 152
		Door Opening	Number of Doors	58	58
			Door Type	Steel Interior	Steel Interior
		Envelope	Category	Insulation	Insulation
			Material	Mineral Wool Batt	Rockwool Batt
			Thickness (mm)	92	92
		Envelope	Category	Gypsum	Gypsum
			Material	Type "x" GWB	Gypsum Regular
			Thickness (mm)	5/8"	5/8"
		1.3.6 SteelStud_P19			
			Length (m)	292	292
			Height (m)	2.9	2.9
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 22	39 x 92
		Door Opening	Number of Doors	18	18
			Door Type	Steel Interior	Steel Interior
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Fire Rated	Gypsum Fire Rated
			Thickness (mm)	5/8"	5/8"
		1.3.7 SteelStud_P17/P20			
			Length (m)	113	113
			Height (m)	2.9	2.9
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 64	39 x 92
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Fire Rated	Gypsum Fire Rated

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Thickness (mm)	5/8"	5/8"
		1.3.8 SteelStud_W2/W3/W4/W5/W9/W11			
			Length (m)	526	526
			Height (m)	2.9	2.9
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 64	39 x 92
		Window	Number of Windows	110	110
			Total Window Area(m2)	498	498
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	Argon Filled	Tin Argon Filled
		Door Opening	Number of Doors	3	3
			Door Type	Steel Interior	Steel Interior
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Regular	Gypsum Regular
			Thickness (mm)	5/8"	5/8"
		Envelope	Category	Insulation	Insulation
			Material	Spray on Foam	Expanded Polystyrene
			Thickness (mm)	60	60
		1.3.9 W_SteelStud_WindowWall_5000			
			Length (m)	61	61
			Height (m)	2.9	2.9
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 64	39 x 92
		Window	Number of Windows	15	15
			Total Window Area(m2)	99	99
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	Argon Filled	Tin Argon Filled
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Regular	Gypsum Regular

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Thickness (mm)	5/8"	5/8"
		Envelope	Category	Insulation	Insulation
			Material	Spray on Foam	Expanded Polystyrene
			Thickness (mm)	60	60
		Envelope	Category	Cladding	Cladding
			Material	Aluminum Cladding	Steel Cladding
			Thickness (mm)	-	Commercial Grade(26Ga)
		1.3.10 SteelStud_P15_GlassWall			
			Length (m)	348	348
			Height (m)	2.9	2.9
			Sheathing	None	None
			Stud Spacing	600 o.c.	600 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 92	39 x 92
		Window	Number of Windows	1	1
			Total Window Area(m2)	795	795
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	Standard	Standard
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Regular	Gypsum Regular
			Thickness (mm)	5/8"	5/8"
		1.3.11 W_SteelStud_P10/P13			
			Length (m)	120	120
			Height (m)	2.9	2.9
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 92	39 x 92
		Door Opening	Number of Doors	9	9
			Door Type	Steel Interior	Steel Interior
		Envelope	Category	Insulation	Insulation
			Material	Mineral Wool Batt	Rockwool Batt
			Thickness (mm)	92	92
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum	Gypsum

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	Input Values IE Inputs
			Thickness (mm)	Moisture 5/8"	Moisture 5/8"
		1.3.12 S_SteelStud_P3/P15_0000			
			Length (m)	19	19
			Height (m)	3.5	3.5
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 152	39 x 152
		Door Opening	Number of Doors	5	5
			Door Type	Steel Interior	Steel Interior
		Envelope	Category	Insulation	Insulation
			Material	Mineral Wool Batt	Rockwool Batt
			Thickness (mm)	152	152
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Regular	Gypsum Regular
			Thickness (mm)	5/8"	5/8"
		1.3.13 S_SteelStud_P7_0000			
			Length (m)	40	40
			Height (m)	3.5	3.5
			Sheathing	None	None
			Stud Spacing	400 o.c.	400 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness (mm)	39 x 92	39 x 92
		Door Opening	Number of Doors	11	11
			Door Type	Steel Interior	Steel Interior
		Envelope	Category	Insulation	Insulation
			Material	Mineral Wool Batt	Rockwool Batt
			Thickness (mm)	92	92
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Regular	Gypsum Regular
			Thickness (mm)	5/8"	5/8"
	1.4 Curtain Wall				
		1.4.1 W_CurtainWall_Exterior_2000/3000			
			Length (m)	69	69
			Height (m)	4.7	4.7
			Viewable Glazing	57	57

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			(%)		
			Spandrel Panel (%)	43	43
			Insulation Thickness (mm)	0	0
			Spandrel Panel Type	Opaque Glass	Opaque Glass
2.) Extra Basic Materials	2.1 Roofing Materials				
			#15 Organic Felt (m2)	24,387.48	24,387.48
			1/2" Moisture Resistant Gypsum Board (m2)	2,941.40	2,941.40
			Extruded Polystyrene (m2) (25mm Thick)	11,062.34	11,062.34
			Galvanized Sheet (Tonnes)	0.99	0.99
			Modified Bitumen membrane (kg)	98,256.07	98,256.07
			Nails (Tonnes)	1.38	1.38
			Roofing Asphalt (kg)	49,471.88	49,471.88
	2.2 Hollow Structural Steel				
			Weight (Tonnes)	0.84	0.84
	2.3 Back Out				
			Galvanized Studs (Tonnes)	-4.46	-4.46
			Screws Nut& Bolts (Tonnes)	-0.37	-0.37
	2.4 Cladding				
			Commercial(26 Ga) Steel Cladding (m2)	2,479.00	2,479.00
	2.5 Polyethylene				
			6 mil polyethylene (m2)	5,125.00	5,125.00

Table 11 Existing BioSciences Buidling Inputs Document.

Existing BioSciences Building Inputs Document					
				Input Values	
Assembly Group	Assembly Type	Assembly Name (**S**:South Wing **W**:West Wing)	Input Fields	Known/ Measured	IE Inputs
1.) Foundations	1.1 Concrete Slab-on-Grade				
		1.1.1 S_Slab-on-Grade_Concrete_6"			
			Length (ft)	78.6	96.2
			Width (ft)	78.6	96.2
			Thickness (in)	6	4
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
		1.1.2 W_Slab-on-Grade_Concrete_6"			
			Length (ft)	98.2	85.1
			Width (ft)	98.2	85.1
			Thickness (in)	6	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
	1.2 Concrete Footing				
		1.2.1 S_Footing_Concrete_Strip_2'Width			
			Length (ft)	323	441.7
			Width (ft)	2	2
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.2 S_Footing_Concrete_Strip_3'Width			
			Length (ft)	186	254.5
			Width (ft)	3	3
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.3 S_Footing_Concrete_G			
			Length (ft)	6.2	7.3
			Width (ft)	6.2	7.3
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Rebar	#5	#5
		1.2.4 S_Footing_Concrete_A/B/C/D/E/F			
			Length (ft)	40.6	47.5
			Width (ft)	40.6	47.5
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#6	#6
		1.2.5 S_Footing_Concrete_H			
			Length (ft)	9.9	12.9
			Width (ft)	9.9	12.9
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.6 W_Footing_Concrete_16"Wide			
			Length (ft)	383	383
			Width (ft)	1.33	1.33
			Thickness (in)	10	10
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.7 W_Footing_Concrete_18"Wide			
			Length (ft)	249	249
			Width (ft)	1.5	1.5
			Thickness (in)	10	10
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.8 W_Footing_Concrete_24"Wide			
			Length (ft)	566	566
			Width (ft)	2	2
			Thickness (in)	10	10
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.9 W_Footing_Concrete_24"Thick			
			Length (ft)	51.4	57.7
			Width (ft)	51.4	57.7
			Thickness (in)	24	19
			Concrete (psi)	-	4000

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.10 S_Stairs_Concrete			
			Length (ft)	185	185
			Width (ft)	3.5	3.5
			Thickness (in)	10	10
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.11 S_Stairs_Concrete_Landings			
			Length (ft)	78	78
			Width (ft)	7.25	7.25
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.12 W_Stairs_Concrete			
			Length (ft)	544	544
			Width (ft)	4.16	4.16
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
2.) Walls	2.1 Cast-in-Place				
		2.1.1 S_Concrete_Cast-in-Place_Foundation_1'Height			
			Length (ft)	221	184.00
			Height (ft)	1	1
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.2 S_Concrete_Cast-in-Place_Foundation_10'8"Height			
			Length (ft)	569	474.00
			Height (ft)	10.66	10.66
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Rebar	#4	#5
		Door Opening	Number of Doors	2	2
			Door Type	-	Steel Interior
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.3 S_Concrete_Cast-in-Place_Basement			
			Length (ft)	443	369.00
			Height (ft)	7	7
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.4 S_Concrete_Cast-in-Place_Stairs/Elevator			
			Length (ft)	556	463.00
			Height (ft)	12.5	12.5
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	10	10
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		Envelope	Category	Cladding	Cladding
			Material	Plaster	Stucco (over porous surface)
			Thickness	-	-
		2.1.5 W_Concrete_Cast-in-Place_Foundation_10"Thick			
			Length (ft)	369	330.00
			Height (ft)	4.5	4.5
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	Input Values IE Inputs
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.6 W_Concrete_Cast-in-Place_Foundation_14"Thick			
			Length (ft)	543	634.00
			Height (ft)	15.75	15.75
			Thickness (in)	14	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.7 W_Concrete_Cast-in-Place_Foundation_8"Thick			
			Length (ft)	711	711.00
			Height (ft)	2	2
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.8 W_Concrete_Cast-in-Place_Exterior_2000/3000			
			Length (ft)	337	337.00
			Height (ft)	12.5	12.5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	8	8
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		Envelope	Category	Cladding	Cladding
			Material	Brick	Brick Standard (Ontario)
			Thickness	-	-

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.9 W_Concrete_Cast-in-Place_Stairs/Elevator/ExteriorDetail			
			Length (ft)	779	779.00
			Height (ft)	12.5	12.5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	5	5
			Door Type	Steel Interior	Steel Interior
		2.1.10 W_Concrete_Cast-in-Place_Exterior_1000			
			Length (ft)	717	717.00
			Height (ft)	12.5	12.5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	7	7
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.11 W_Concrete_Cast-in-Place_Exterior_4000			
			Length (ft)	116	116.00
			Height (ft)	5	5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Cladding	Cladding
			Material	Brick	Brick Standard (Ontario)
			Thickness	-	-
			Category	Vapour	Vapour

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
				Barrier	Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
	2.2 Concrete Block Wall				
		2.2.1 S_Concrete BlockWall_SubBasement			
		Door Opening	Length (ft)	246	246
			Height (ft)	9.66	9.66
			Rebar	-	#4
			Number of Doors	7	7
			Door Type	Steel Interior	Steel Interior
		2.2.2 S_Concrete BlockWall_Roof			
		Door Opening	Length (ft)	328	328
			Height (ft)	7	7
			Rebar	-	#4
			Number of Doors	4	4
			Door Type	Steel Exterior	Steel Exterior
		2.2.3 S_Concrete BlockWall_Exterior_3'6"Height			
		Door Opening	Length (ft)	536	536
			Height (ft)	3.5	3.5
			Rebar	-	#4
			Number of Doors	4	4
			Door Type	Steel Exterior	Steel Exterior
		Envelope	Category	Cladding	Cladding
			Material	Brick Standard (Ontario)	Brick Standard (Ontario)
			Thickness	-	-
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.2.4 S_Concrete BlockWall_Exterior_7'Height			
		Envelope	Length (ft)	884	884
			Height (ft)	7	7
			Rebar	-	#4
			Category	Cladding	Cladding
			Material	Brick Standard	Brick Standard

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
				(Ontario)	(Ontario)
			Thickness	-	-
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.2.5 S_Concrete BlockWall_Interior			
			Length (ft)	2788	2788
			Height (ft)	12.5	12.5
			Rebar	-	#4
		Door Opening	Number of Doors	81	81
			Door Type	Solid Wood	Solid Wood
		2.2.6 W_Concrete BlockWall_0000			
			Length (ft)	150	150
			Height (ft)	15.75	15.75
			Rebar	-	#4
		Door Opening	Number of Doors	3	3
			Door Type	Steel Interior	Steel Interior
		2.2.7 W_Concrete BlockWall_Interior_1000/2000/3000			
			Length (ft)	510	510
			Height (ft)	12.5	12.5
			Rebar	-	#4
		Door Opening	Number of Doors	8	8
			Door Type	Solid Wood	Solid Wood
		2.2.8 W_Concrete BlockWall_5000			
			Length (ft)	270	270
			Height (ft)	4	4
			Rebar	-	#4
		Envelope	Category	Cladding	Cladding
			Material	Brick Standard (Ontario)	Brick Standard (Ontario)
			Thickness	-	-
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
	2.3 Steel Stud				
		2.3.1 S_SteelStud_ServiceStrip			
			Length (ft)	1790	1790
			Height (ft)	12.5	12.5

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Sheathing	Plywood	Plywood
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	112	112
			Total Window Area(ft2)	6484	6484
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Door Opening	Number of Doors	4	4
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	1
		2.3.2 W_SteelStud_Interior_1000/2000/3000			
			Length (ft)	5619	5619
			Height (ft)	12.5	12.5
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Door Opening	Number of Doors	133	133
			Door Type	Solid Wood	Solid Wood
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Moisture
			Thickness (in)	-	5/8"
		2.3.3 W_SteelStud_Exterior_1000/2000/3000			
			Length (ft)	892	892
			Height (ft)	12.5	12.5
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Heavy Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	68	68
			Total Window Area(ft2)	398	398

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Reg
			Thickness (in)	-	5/8"
		Envelope	Category	Insulation	Insulation
			Material	Fiberglass Batt	Fiberglass Batt
			Thickness (in)	-	2"
		2.3.4 W_SteelStud_WindowWall_5000			
			Length (ft)	272	272
			Height (ft)	9.83	9.83
			Sheathing	Plywood	Plywood
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	17	17
			Total Window Area(ft2)	1101	1101
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Moisture
			Thickness (in)	-	5/8"
		Envelope	Category	Cladding	Cladding
			Material	Ceramic Tiles	Brick Spilt Faced
			Thickness	-	-
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
		2.3.5 W_SteelStud_ExteriorDoorWall_5000			
			Length (ft)	24	24
			Height (ft)	7	7

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Door Opening	Number of Doors	8	8
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		2.3.6 W_SteelStud_Exterior_5000			
			Length (ft)	726	726
			Height (ft)	9.83	9.83
			Sheathing	Plywood	Plywood
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Heavy Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Plaster Board	Gypsum Reg
			Thickness (in)	-	5/8"
		Envelope	Category	Cladding	Cladding
			Material	Exterior Tiles	Brick Standard (Ontario)
			Thickness (in)	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
	2.4 Wood Stud				
		2.4.1 S_WoodStud_Pipe/DuctSpace			
			Length (ft)	523	523
			Height (ft)	12.5	12.5
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Kiln Dried
			Stud Thickness	-	2x4
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Plaster Board	Gypsum Reg

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Thickness (in)	-	5/8"
		2.4.2 W_WoodStud_PartitionWall_1000			
			Length (ft)	92	92
			Height (ft)	7	7
			Sheathing	None	None
			Stud Spacing	-	24 o.c.
			Stud Weight	-	Kiln Dried
			Stud Thickness	-	2x3
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Reg
			Thickness (in)	-	1/2"
	2.5 Concrete Tilt Up				
		2.5.1 W_Concrete_TiltUp_Exterior_2000/3000			
			Length (ft)	1022	681
			Height (ft)	12.5	12.5
			Thickness (in)	4	6
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		Envelope	Category	Cladding	Cladding
			Material	Stucco	Stucco (over porous surface)
			Thickness (in)	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
		2.5.2 W_Concrete_TiltUp_Exterior_4000			
			Length (ft)	540	360
			Height (ft)	5	5
			Thickness (in)	4	6
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		Envelope	Category	Cladding	Cladding
			Material	Stucco	Stucco (over porous surface)
			Thickness (in)	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene	Polystyrene

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
				Extruded	Extruded
			Thickness (in)	-	2"
		2.5.3 W_Concrete_TiltUp_Railing_5000			
			Length (ft)	744	744
			Height (ft)	5.3	5.3
			Thickness (in)	6	6
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
	2.6 Curtain Wall				
		2.6.1 W_CurtainWall_2000/3000			
			Length (ft)	227	227
			Height (ft)	12.5	12.5
			Viewable Glazing (%)	38	38
			Spandrel Panel (%)	62	62
			Insulation Thickness (in)	2	2
			Spandrel Panel Type	Opaque Glass	Opaque Glass
		2.6.2 W_CurtainWall_4000			
			Length (ft)	82	82
			Height (ft)	5	5
			Viewable Glazing (%)	0	0
			Spandrel Panel (%)	100	100
			Insulation Thickness (in)	2	2
			Spandrel Panel Type	Opaque Glass	Opaque Glass
3.) Mixed Columns and Beams	3.1 Concrete Columns				
		3.1.1 S_Column_Concrete_Basement_1			
			Number of Beams	10	10
			Number of Columns	19	19
			Floor to Floor Height (ft)	9.7	9.7
			Bay Sizes (ft)	28	28
			Supported Span (ft)	16	16
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
		3.1.2 S_Columns_Concrete_Basement_2			
			Number of Beams	10	10

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	IE Inputs
			Number of Columns	22	22
			Floor to Floor Height (ft)	9.7	9.7
			Bay Sizes (ft)	14.8	14.8
			Supported Span (ft)	16	16
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
		3.1.3 S_Columns_Concrete_1			
			Number of Beams	40	40
			Number of Columns	77	77
			Floor to Floor Height (ft)	12.5	12.5
			Bay Sizes (ft)	28	28
			Supported Span (ft)	16	16
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
		3.1.4 S_Columns_Concrete_2			
			Number of Beams	52	52
			Number of Columns	75	75
			Floor to Floor Height (ft)	12.5	12.5
			Bay Sizes (ft)	14.8	14.8
			Supported Span (ft)	16	16
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
		3.1.5 W_Columns_Concrete_1000			
			Number of Beams	0	0
			Number of Columns	60	60
			Floor to Floor Height (ft)	15.75	15.75
			Bay Sizes (ft)	25	25
			Supported Span (ft)	14	14
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	-	-
		3.1.6 W_Columns_Concrete_2000/3000/4000			
			Number of Beams	0	0

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Number of Columns	187	187
			Floor to Floor Height (ft)	12.5	12.5
			Bay Sizes (ft)	25	25
			Supported Span (ft)	14	14
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	-	-
		3.1.7 W_Columns_Concrete_5000			
			Number of Beams	0	0
			Number of Columns	63	63
			Floor to Floor Height (ft)	5	5
			Bay Sizes (ft)	25	25
			Supported Span (ft)	14	14
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	-	-
		3.1.8 W_Columns_Concrete_Roof			
			Number of Beams	0	0
			Number of Columns	60	60
			Floor to Floor Height (ft)	9.75	9.75
			Bay Sizes (ft)	25	25
			Supported Span (ft)	14	14
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	-	-
4.) Floors	4.1 Concrete Suspended Slab				
		4.1.1 S_Floor_Concrete_SuspenedSlab			
			Floor Width (ft)	2486.2	2486.2
			Span (ft)	16	16
			Concrete (psi)	-	4000
			Concrete Flyash %	-	avg
			Live Load (psf)	-	75
		4.1.2 W_Floor_Concrete_SuspenedSlab			
			Floor Width (ft)	824	824
			Span (ft)	14	14
			Concrete (psi)	-	4000
			Concrete Flyash %	-	avg

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Live Load (psf)	-	75
	4.2 Concrete Double T				
		4.2.1 W_Floor_Concrete_DoubleT			
			Number of Bays	155	155
			Bay Sizes (ft)	25	25
			Span (ft)	14	14
			Topping	Included	Included
			Live Load (psf)	-	75
5.) Roofs	5.1 Concrete Suspended Slab				
		5.1.1 S_Roof_Concrete_SuspendedSlab			
			Roof Width (ft)	613.3	613.3
			Span (ft)	16	16
			Concrete (psi)	-	4000
			Concrete Flyash %	-	avg
			Live Load (psf)	-	75
		5.1.2 W_Roof_Concrete_SuspendedSlab			
			Roof Width (ft)	1161	1161
			Span (ft)	14	14
			Concrete (psi)	-	4000
			Concrete Flyash %	-	avg
			Live Load (psf)	-	75
6.) Extra Basic Materials	6.1 Roofing Materials				
		6.1.1 S/W_RoofingMaterials			
			#15 Organic Felt (100sf)	4850.94	4850.94
			Ballast (lbs)	1426806.75	1426806.75
			Extruded Polystyrene (sf, 1"thick)	111780.52	111780.52
			Galvanized Sheet (tons)	3.25	3.25
			Polyethylene Filter Fabric (tons)	0.79	0.79
			Roofing Asphalt (lbs)	100847.20	100847.20

Table 12 Full Construction of New BioSciences Building Inputs Document.

Full Construction of New BioSciences Building Inputs Document					
				Input Values	
Assembly Group	Assembly Type	Assembly Name (**S**:South Wing **W**:West Wing)	Input Fields	Known/ Measured	IE Inputs
1.) Foundations	1.1 Concrete Slab-on-Grade				
		1.1.1 S_Slab-on-Grade_Concrete_6"			
			Length (ft)	78.6	96.2
			Width (ft)	78.6	96.2
			Thickness (in)	6	4
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
		1.1.2 W_Slab-on-Grade_Concrete_6"			
			Length (ft)	98.2	85.1
			Width (ft)	98.2	85.1
			Thickness (in)	6	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
	1.2 Concrete Footing				
		1.2.1 S_Footing_Concrete_Strip_2'Width			
			Length (ft)	323	441.7
			Width (ft)	2	2
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.2 S_Footing_Concrete_Strip_3'Width			
			Length (ft)	186	254.5
			Width (ft)	3	3
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.3 S_Footing_Concrete_G			
			Length (ft)	6.2	7.3
			Width (ft)	6.2	7.3
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Rebar	#5	#5
		1.2.4 S_Footing_Concrete_A/B/C/D/E/F			
			Length (ft)	40.6	47.5
			Width (ft)	40.6	47.5
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#6	#6
		1.2.5 S_Footing_Concrete_H			
			Length (ft)	9.9	12.9
			Width (ft)	9.9	12.9
			Thickness (in)	26	19
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.6 W_Footing_Concrete_16"Wide			
			Length (ft)	383	383
			Width (ft)	1.33	1.33
			Thickness (in)	10	10
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.7 W_Footing_Concrete_18"Wide			
			Length (ft)	249	249
			Width (ft)	1.5	1.5
			Thickness (in)	10	10
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.8 W_Footing_Concrete_24"Wide			
			Length (ft)	566	566
			Width (ft)	2	2
			Thickness (in)	10	10
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.9 W_Footing_Concrete_24"Thick			
			Length (ft)	51.4	57.7
			Width (ft)	51.4	57.7
			Thickness (in)	24	19
			Concrete (psi)	-	4000

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.10 S_Stairs_Concrete			
			Length (ft)	185	185
			Width (ft)	3.5	3.5
			Thickness (in)	10	10
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.11 S_Stairs_Concrete_Landings			
			Length (ft)	78	78
			Width (ft)	7.25	7.25
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.12 W_Stairs_Concrete			
			Length (ft)	544	544
			Width (ft)	4.16	4.16
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
2.) Walls					
	2.1 Cast-in-Place				
		2.1.1 S_Concrete_Cast-in-Place_Foundation_1'Height			
			Length (ft)	221	184.00
			Height (ft)	1	1
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.2 S_Concrete_Cast-in-Place_Foundation_10'8"Height			
			Length (ft)	569	474.00
			Height (ft)	10.66	10.66
			Thickness (in)	10	12
			Concrete (psi)	-	4000

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	2	2
			Door Type	-	Steel Interior
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.3 S_Concrete_Cast-in-Place_Basement			
			Length (ft)	443	369.00
			Height (ft)	7	7
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.4 S_Concrete_Cast-in-Place_Stairs/Elevator			
			Length (ft)	556	463.00
			Height (ft)	13.2	13.2
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	10	10
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		Envelope	Category	Cladding	Cladding
			Material	Plaster	Stucco (over porous surface)
			Thickness	-	-
		2.1.5 W_Concrete_Cast-in-Place_Foundation_10"Thick			
			Length (ft)	369	330.00
			Height (ft)	4.5	4.5
			Thickness (in)	10	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Rebar	#4	#5
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.6 W_Concrete_Cast-in-Place_Foundation_14"Thick			
			Length (ft)	543	634.00
			Height (ft)	15.75	15.75
			Thickness (in)	14	12
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.7 W_Concrete_Cast-in-Place_Foundation_8"Thick			
			Length (ft)	711	711.00
			Height (ft)	2	2
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.8 W_Concrete_Cast-in-Place_Exterior_2000/3000			
			Length (ft)	337	337.00
			Height (ft)	13.2	13.2
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	8	8
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		Envelope	Category	Cladding	Cladding
			Material	Brick	Brick Standard (Ontario)

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Thickness	-	-
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.9 W_Concrete_Cast-in-Place_Stairs/Elevator/ExteriorDetail			
			Length (ft)	779	779.00
			Height (ft)	13.2	13.2
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	5	5
			Door Type	Steel Interior	Steel Interior
		2.1.10 W_Concrete_Cast-in-Place_Exterior_1000			
			Length (ft)	717	717.00
			Height (ft)	13.2	13.2
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Door Opening	Number of Doors	7	7
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.1.11 W_Concrete_Cast-in-Place_Exterior_4000			
			Length (ft)	116	116.00
			Height (ft)	5	5
			Thickness (in)	8	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		Envelope	Category	Cladding	Cladding
			Material	Brick	Brick Standard (Ontario)
			Thickness	-	-

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
	2.2 Concrete Block Wall				
		2.2.1 S_Concrete BlockWall_SubBasement			
		Door Opening	Length (ft)	246	184.5
			Height (ft)	9.66	9.66
			Rebar	-	#4
			Number of Doors	7	7
			Door Type	Steel Interior	Steel Interior
		2.2.2 S_Concrete BlockWall_Roof			
		Door Opening	Length (ft)	328	328
			Height (ft)	7	7
			Rebar	-	#4
			Number of Doors	4	4
			Door Type	Steel Exterior	Steel Exterior
		2.2.3 S_Concrete BlockWall_Exterior_3'6"Height			
		Door Opening	Length (ft)	536	536
			Height (ft)	3.5	3.5
			Rebar	-	#4
			Number of Doors	4	4
			Door Type	Steel Exterior	Steel Exterior
		Envelope	Category	Cladding	Cladding
			Material	Brick Standard (Ontario)	Brick Standard (Ontario)
			Thickness	-	-
			Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		2.2.4 S_Concrete BlockWall_Exterior_7'Height			
			Length (ft)	884	884
			Height (ft)	7	7
			Rebar	-	#4
		Envelope	Category	Cladding	Cladding
			Material	Brick	Brick

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Thickness	Standard (Ontario) -	Standard (Ontario) -
			Category Material Thickness	Vapour Barrier Polyethylene 6 mil -	Vapour Barrier Polyethylene 6 mil -
		2.2.5 S_Concrete BlockWall_Interior			
		Door Opening	Length (ft)	2788	2788
			Height (ft)	13.2	13.2
			Rebar	-	#4
			Number of Doors	81	81
			Door Type	Solid Wood	Solid Wood
		2.2.6 W_Concrete BlockWall_0000			
		Door Opening	Length (ft)	150	150
			Height (ft)	15.75	15.75
			Rebar	-	#4
			Number of Doors	3	3
			Door Type	Steel Interior	Steel Interior
		2.2.7 W_Concrete BlockWall_Interior_1000/2000/3000			
		Door Opening	Length (ft)	510	510
			Height (ft)	13.2	13.2
			Rebar	-	#4
			Number of Doors	8	8
			Door Type	Solid Wood	Solid Wood
		2.2.8 W_Concrete BlockWall_5000			
		Envelope	Length (ft)	270	270
			Height (ft)	4	4
			Rebar	-	#4
			Category Material Thickness	Cladding Brick Standard (Ontario) -	Cladding Brick Standard (Ontario) -
			Category Material Thickness	Vapour Barrier Polyethylene 6 mil -	Vapour Barrier Polyethylene 6 mil -
	2.3 Steel Stud				
		2.3.1 S_SteelStud_ServiceStrip			
			Length (ft)	1790	1790
			Height (ft)	13.2	13.2

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Sheathing	Plywood	Plywood
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	112	112
			Total Window Area(ft2)	6484	6484
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Door Opening	Number of Doors	4	4
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	1
		2.3.2 W_SteelStud_Interior_1000/2000/3000			
			Length (ft)	5619	5619
			Height (ft)	13.2	13.2
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Door Opening	Number of Doors	133	133
			Door Type	Solid Wood	Solid Wood
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Moisture
			Thickness (in)	-	5/8"
		2.3.3 W_SteelStud_Exterior_1000/2000/3000			
			Length (ft)	892	892
			Height (ft)	13.2	13.2
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Heavy Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	68	68
			Total Window Area(ft2)	398	398

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	Input Values IE Inputs
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Reg
			Thickness (in)	-	5/8"
		Envelope	Category	Insulation	Insulation
			Material	Fiberglass Batt	Fiberglass Batt
			Thickness (in)	-	2"
		2.3.4 W_SteelStud_WindowWall_5000			
			Length (ft)	272	272
			Height (ft)	13.2	13.2
			Sheathing	Plywood	Plywood
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Window	Number of Windows	17	17
			Total Window Area(ft2)	1101	1101
			Frame Type	Fixed, Aluminum	Fixed, Aluminum
			Glazing	-	Standard
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Moisture
			Thickness (in)	-	5/8"
		Envelope	Category	Cladding	Cladding
			Material	Ceramic Tiles	Brick Spilt Faced
			Thickness	-	-
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
		2.3.5 W_SteelStud_ExteriorDoorWall_5000			
			Length (ft)	24	24
			Height (ft)	7	7

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	Input Values IE Inputs
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Light Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Door Opening	Number of Doors	8	8
			Door Type	Aluminum Ext 80% Glazing	Aluminum Ext 80% Glazing
		2.3.6 W_SteelStud_Exterior_5000			
			Length (ft)	726	726
			Height (ft)	13.2	13.2
			Sheathing	Plywood	Plywood
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Heavy Gauge
			Stud Thickness	-	1 5/8 x 3 5/8
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Plaster Board	Gypsum Reg
			Thickness (in)	-	5/8"
		Envelope	Category	Cladding	Cladding
			Material	Exterior Tiles	Brick Standard (Ontario)
			Thickness (in)	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
		Envelope	Category	Vapour Barrier	Vapour Barrier
			Material	Polyethylene 6 mil	Polyethylene 6 mil
			Thickness	-	-
	2.4 Wood Stud				
		2.4.1 S_WoodStud_Pipe/DuctSpace			
			Length (ft)	523	523
			Height (ft)	13.2	13.2
			Sheathing	None	None
			Stud Spacing	-	16 o.c.
			Stud Weight	-	Kiln Dried
			Stud Thickness	-	2x4
		Envelope	Category	Gypsum	Gypsum
			Material	Gypsum Plaster Board	Gypsum Reg

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
			Thickness (in)	-	5/8"
		2.4.2 W_WoodStud_PartitionWall_1000			
			Length (ft)	92	92
			Height (ft)	7	7
			Sheathing	None	None
			Stud Spacing	-	24 o.c.
			Stud Weight	-	Kiln Dried
			Stud Thickness	-	2x3
		Envelope	Category	Gypsum	Gypsum
			Material	Plaster Board	Gypsum Reg
			Thickness (in)	-	1/2"
	2.5 Concrete Tilt Up				
		2.5.1 W_Concrete_TiltUp_Exterior_2000/3000			
			Length (ft)	1022	681
			Height (ft)	13.2	13.2
			Thickness (in)	4	6
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		Envelope	Category	Cladding	Cladding
			Material	Stucco	Stucco (over porous surface)
			Thickness (in)	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene Extruded	Polystyrene Extruded
			Thickness (in)	-	2"
		2.5.2 W_Concrete_TiltUp_Exterior_4000			
			Length (ft)	540	360
			Height (ft)	5	5
			Thickness (in)	4	6
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		Envelope	Category	Cladding	Cladding
			Material	Stucco	Stucco (over porous surface)
			Thickness (in)	-	-
		Envelope	Category	Insulation	Insulation
			Material	Polystyrene	Polystyrene

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values: Known/ Measured	Input Values: IE Inputs
				Extruded	Extruded
			Thickness (in)	-	2"
		2.5.3 W_Concrete_TiltUp_Railing_5000			
			Length (ft)	744	744
			Height (ft)	5.3	5.3
			Thickness (in)	6	6
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
	2.6 Curtain Wall				
		2.6.1 W_CurtainWall_2000/3000			
			Length (ft)	227	227
			Height (ft)	13.2	13.2
			Viewable Glazing (%)	38	38
			Spandrel Panel (%)	62	62
			Insulation Thickness (in)	2	2
			Spandrel Panel Type	Opaque Glass	Opaque Glass
		2.6.2 W_CurtainWall_4000			
			Length (ft)	82	82
			Height (ft)	5	5
			Viewable Glazing (%)	0	0
			Spandrel Panel (%)	100	100
			Insulation Thickness (in)	2	2
			Spandrel Panel Type	Opaque Glass	Opaque Glass
3.) Mixed Columns and Beams					
	3.1 Concrete Columns				
		3.1.1 S_Column_Concrete_Basement_1			
			Number of Beams	10	10
			Number of Columns	19	19
			Floor to Floor Height (ft)	9.7	9.7
			Bay Sizes (ft)	28	28
			Supported Span (ft)	16	16
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
		3.1.2 S_Columns_Concrete_Basement_2			

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values	
				Known/ Measured	IE Inputs
			Number of Beams	10	10
			Number of Columns	22	22
			Floor to Floor Height (ft)	9.7	9.7
			Bay Sizes (ft)	14.8	14.8
			Supported Span (ft)	16	16
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
		3.1.3 S_Columns_Concrete_1			
			Number of Beams	40	40
			Number of Columns	77	77
			Floor to Floor Height (ft)	13.2	13.2
			Bay Sizes (ft)	28	28
			Supported Span (ft)	16	16
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
		3.1.4 S_Columns_Concrete_2			
			Number of Beams	52	52
			Number of Columns	75	75
			Floor to Floor Height (ft)	13.2	13.2
			Bay Sizes (ft)	14.8	14.8
			Supported Span (ft)	16	16
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
		3.1.5 W_Columns_Concrete_1000			
			Number of Beams	0	0
			Number of Columns	60	60
			Floor to Floor Height (ft)	15.75	15.75
			Bay Sizes (ft)	25	25
			Supported Span (ft)	14	14
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	-	-
		3.1.6 W_Columns_Concrete_2000/3000/4000			

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	IE Inputs
			Number of Beams	0	0
			Number of Columns	187	187
			Floor to Floor Height (ft)	13.2	13.2
			Bay Sizes (ft)	25	25
			Supported Span (ft)	14	14
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	-	-
		3.1.7 W_Columns_Concrete_5000			
			Number of Beams	0	0
			Number of Columns	63	63
			Floor to Floor Height (ft)	5	5
			Bay Sizes (ft)	25	25
			Supported Span (ft)	14	14
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	-	-
		3.1.8 W_Columns_Concrete_Roof			
			Number of Beams	0	0
			Number of Columns	60	60
			Floor to Floor Height (ft)	13.2	13.2
			Bay Sizes (ft)	25	25
			Supported Span (ft)	14	14
			Live Load (psf)	-	75
			Column Type	Concrete	Concrete
			Beam Type	-	-
4.) Floors					
	4.1 Concrete Suspended Slab				
		4.1.1 S_Floor_Concrete_SuspenedSlab			
			Floor Width (ft)	2486.2	2486.2
			Span (ft)	16	16
			Concrete (psi)	-	4000
			Concrete Flyash %	-	avg
			Live Load (psf)	-	75
		4.1.2 W_Floor_Concrete_SuspenedSlab			
			Floor Width (ft)	824	824
			Span (ft)	14	14

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Input Fields	Input Values Known/ Measured	Input Values IE Inputs
			Concrete (psi)	-	4000
			Concrete Flyash %	-	avg
			Live Load (psf)	-	75
	4.2 Concrete Double T				
		4.2.1 W_Floor_Concrete_DoubleT			
			Number of Bays	155	155
			Bay Sizes (ft)	25	25
			Span (ft)	14	14
			Topping	Included	Included
			Live Load (psf)	-	75
5.) Roofs					
	5.1 Concrete Suspended Slab				
		5.1.1 S_Roof_Concrete_SuspendedSlab			
			Roof Width (ft)	613.3	613.3
			Span (ft)	16	16
			Concrete (psi)	-	4000
			Concrete Flyash %	-	avg
			Live Load (psf)	-	75
		5.1.2 W_Roof_Concrete_SuspendedSlab			
			Roof Width (ft)	1161	1161
			Span (ft)	14	14
			Concrete (psi)	-	4000
			Concrete Flyash %	-	avg
			Live Load (psf)	-	75
6.) Extra Basic Materials					
	6.1 Roofing Materials				
			#15 Organic Felt (m2)	24,387.48	24,387.48
			1/2" Moisture Resistant Gypsum Board (m2)	2,941.40	2,941.40
			Extruded Polystyrene (m2) (25mm Thick)	11,062.34	11,062.34
			Galvanized Sheet (Tonnes)	0.99	0.99
			Modified Bitumen membrane (kg)	98,256.07	98,256.07
			Nails (Tonnes)	1.38	1.38
			Roofing Asphalt (kg)	49,471.88	49,471.88

Appendix C Assumptions Documents

This Appendix Contains all of the assumptions that were required in order to complete the building models due to information that was not known and/or could not be measured from available building information.

Table 13 Existing BioSciences Building Input Assumptions Document.

Existing BioSciences Building Input Assumptions Document			
Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
1.) Foundation	In the Impact Estimator, Slab-on-Grade inputs are limited to being either a 4” or 8” thickness. Since the actual SOG thickness for the Existing BioSciences building was not exactly 4” or 8” thick. Also the Impact Estimator limits the thickness of footings to be between 7.5” and 19.7” thick. As there are a number of cases where footing thicknesses exceed 19”, the lengths of each footing were adjusted accordingly to maintain the same volume of concrete. Lastly, the concrete stairs were modelled as footings to be able to select the appropriate rebar specifications (i.e. Stairs_Concrete_TotalLength). An average thickness of stairs was applied to the total length in the building.		
	1.1 Concrete_Slab-on-Grade		
		1.1.1 S_Slab-on-Grade_Concrete_6"	The area of this slab had to be adjusted so that the thickness would be able to fit into the 4" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Slab Area) x (Actual Slab Thickness)) /(4”/12)] = sqrt[(6175' x (6”/12))/(4”/12)] = 96 ft Assume Concrete: 4000 psi Assume FlyAsh%: Average
		1.1.2 W_Slab-on-Grade_Concrete_6"	The area of this slab had to be adjusted so that the thickness fit into the 8" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Slab Area) x (Actual Slab Thickness)) /(8”/12)] = sqrt[(98.1' x (6”/12))/(8”/12)] = 85 ft Assume Concrete: 4000 psi Assume FlyAsh%: Average
	1.2 Concrete Footing		

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.2.1 S_Footing_Concrete_Strip_2'Wide	The length of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The thicknesses were set at 19” and the following calculation was done in order to determine appropriate length inputs for the footing; = (Volume of Concrete)/(Width)/(New Thickness) = (1399 ft3)/(2ft)/(19"x12) = 442 ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.2 S_Footing_Concrete_Strip_3'Wide	The length of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The thicknesses were set at 19” and the following calculation was done in order to determine appropriate length input for the footing; = (Volume of Concrete)/(Width)/(New Thickness) = (1209 ft3)/(3ft)/(19"x12) = 254.5 ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.3 S_Footing_Concrete_G	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The thicknesses were set at 19” and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness))/(19”/12)] = sqrt[(39ft2 x (26”/12))/(19”/12)] = 7.3ft Assume concrete 4000 psi Assume FlyAsh%: Average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.2.4 S_Footing_Concrete_A/B/C/D/E/F	The volume of these footing slabs were calculated since the thicknesses varied. Then the total volume of the footing was then divided by the set slab thickness of 19" to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. This gave the area of the slab with a thickness of 19" from which the new Length and Width were determined; = sqrt[(Total Volume of Footings A/B/C/D/E/F)/(19"/12)] = sqrt[(3577ft3)/(19”/12)] = 47.5ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.5 S_Footing_Concrete_H	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The thicknesses were set at 19” and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness))/(19”/12)] = sqrt[(99ft2 x (32”/12))/(19”/12)] = 12.9ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.6 W_Footing_Concrete_16"Wide	Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.7 W_Footing_Concrete_18"Wide	Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.8 W_Footing_Concrete_24"Wide	Assume concrete 4000 psi Assume FlyAsh%: Average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.2.9 W_Footing_Concrete_2'Thick	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7”. The thicknesses were set at 19” and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness))/(19”/12)] = sqrt[(2639ft2 x (32”/12))/(19”/12)] = 57.7ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.10 S_Stairs_Concrete	Thickness of the stairs were estimated to be 10" based on measurements done on the building drawings.
		1.2.11 S_Stairs_Concrete_Landings	No assumption necessary
		1.2.12 W_Stairs_Concrete	No stair details could be found other then a quite simple diagram on structural drawing 065-07-030. Stairs specification were taken from this drawing.
2.)Walls	One major assumption for the west wing of the BioSciences building was that the 3000 level has the same floor plan as the 2000 level for the West Wing. The plans for the West Wing's 3000 level do not exist at UBC's Records Department. In modeling the respective wall types, the doors and windows were recorded with the exact wall they appeared in. Envelope and opening details were also gathered from numerous architectural drawings. A few assumptions and calculations were made in order to complete the modelling of the walls in the building, such as adjusting the length of the concrete in cast-in-place walls to accommodate wall thickness limitations in the Impact Estimator.		
	2.1 Cast-in-Place		
		2.1.1 S_Concrete_Cast-in-Place_Foundation_1'Height	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12”] = (221 ft) x [(10")/12] = 184 ft Assume concrete 4000 psi Assume FlyAsh%: Average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
			Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.1.2 S_Concrete_Cast-in-Place_Foundation_10'8"Height	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12”] = (569ft)x[(10”)/12] = 474ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.1.3 S_Concrete_Cast-in-Place_Basement	This wall was adjusted by a factor in order to fit one of the selections of either 8" of12" thickness in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/12”] = (443ft)x[(10”)/12] = 396ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		2.1.4 S_Concrete_Cast-in-Place_Stair/Elevator	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12”] = (556ft)x[(10”)/12] = 463ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume Stucco (over a porous surface) instead of plaster
		2.1.5 W_Concrete_Cast-in-Place_10"Thick	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12”] = (396ft)x[(10”)/12] = 330ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier
		2.1.6 W_Concrete_Cast-in-Place_14"Thick	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12”] = (543ft)x[(14”)/12] = 634ft

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
			Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.1.7 W_Concrete_Cast-in-Place_8"Thick	Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier
		2.1.8 W_Concrete_Cast-in-Place_Exterior_2000/3000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.1.9 W_Concrete_Cast-in-Place_Stairs/Elevator/ExteriorDetail	Assume concrete 4000 psi Assume FlyAsh%: Average Assume rebar #5
		2.1.10 W_Concrete_Cast-in-Place_Exterior_1000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.1.11 W_Concrete_Cast-in-Place_Exterior_5000	Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
	2.2 Concrete Block Wall		
		2.2.1 S_Concrete_BlockWall_SubBasement	Assume Rebar #4
		2.2.2 S_Concrete_BlockWall_Roof	Assume concrete block for brick Assume Rebar #4
		2.2.3 S_Concrete_BlockWall_Exterior_3'6"Height	Assume Rebar #4 Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.2.4 S_Concrete_BlockWall_Exterior_7'Height	Assume Rebar #4 Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.2.5 S_Concrete_BlockWall_Interior	Assume Rebar #4 Assume stucco (over porous surface) for plaster
		2.2.6 W_Concrete_BlockWall_0000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume Rebar #4
		2.2.7 W_Concrete_BlockWall_1000/2000/3000	Assume Rebar #4
		2.2.8 W_Concrete_BlockWall_5000	Assume Rebar #4 Assume 6 mil polyethylene vapour barrier since this is an exterior wall
	2.3 Steel Stud		

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		2.3.1 S_SteelStud_ServiceStrip	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the south wings exterior walls were not being renovated, the windows where modelled in this service strip which is part of the renovations. The service strip therefore spans from the floor to the ceiling. Assume spacing is 16" o.c. Assume that window frames are fixed since only a small minority is operable.
		2.3.2 W_SteelStud_Interior_1000/2000/3000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume no sheathing since this is an interior wall Assume Light Gauge since this is an interior wall Assume spacing is 16" o.c. Assume moisture resistant gypsum plasterboard for use in laboratories
		2.3.3 W_SteelStud_Exterior_1000/2000/3000	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the west wings exterior walls were not being renovated, the windows where modelled with the interior portion of the wall which was renovated. Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume heavy gauge since this is an exterior wall Assume spacing is 16" o.c Assume windows frames are fixed since only a small minority is operable Assume reg gypsum board
		2.3.4 W_SteelStud_WindowWall_5000	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the west wings exterior walls were not being renovated, the windows where modelled with the interior portion of the wall labelled the window wall. The window wall therefore spans from the floor to the ceiling. Assume heavy gauge since this is an exterior wall Assume windows frames are fixed since only a small minority is operable Assume spacing is 16" o.c.

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
			Assume split faced brick for ceramic tile Assume reg gypsum board Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.3.5 W_SteelStud_ExteriorDoorWall_5000	Assume Light Gauge since this is an interior wall Assume spacing is 16" o.c.
		2.3.6 W_SteelStud_Exterior_5000	Assume heavy gauge since this is an exterior wall Assume spacing is 16" o.c Assume split faced brick for ceramic tile Assume 6 mil polyethylene vapour barrier since this is an exterior wall
	2.4 Wood Stud		
		2.4.1 S_WoodStud_Pipe/DuctSpace	Assume Kiln Dried Assume 16" o.c.
		2.4.2 W_WoodStud_PartionWall_1000	Assume Kiln Dried Assume 24" o.c. for partition wall
	2.5 Concrete Tilt Up		
		2.5.1 W_Concrete_TiltUp_Exterior_2000/3000	This wall was adjusted by a factor in order to fit one of the selections of either 6" of 8" thickness, for concrete tilt up walls, in Impact Estimator. In this case the wall was adjusted to a 6" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/6”] = (1022ft)x[(4”)/6] = 681ft Assume concrete 4000 psi Assume FlyAsh%: Average
		2.5.2 W_Concrete_TiltUp_Exterior_4000	This wall was adjusted by a factor in order to fit one of the selections of either 6" of 8" thickness, for concrete tilt up walls, in Impact Estimator. In this case the wall was adjusted to a 6" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/6”] = (540ft)x[(4”)/6] = 360ft

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
			Assume concrete 4000 psi Assume FlyAsh%: Average
		2.5.3 W_Concrete_TiltUp_Railing_5000	Assume concrete 4000 psi Assume FlyAsh%: Average
	2.6 Curtain Wall		
		2.6.1 W_CurtainWall_2000/3000	Percent viewable glazing was calculated from elevation drawing 065-06-066
		2.6.2 W_CurtainWall_4000	Percent viewable glazing was calculated from elevation drawing 065-06-066
3.) Columns	The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. This being the case, beams (only for the south wing) and concrete columns were counted on each floor and each associated floor area was measured. Since this is an institutional building the live loading was assumed to be 75 psf.		
	3.1 Concrete Columns		
		3.1.1 S_Column_Concrete_Basement_1	Column plan for the basement level was not able to be found so the column plan for the first floor was assumed to be adequate
		3.1.2 S_Column_Concrete_Basement_2	Column plan for the basement level was not able to be found so the column plan for the first floor was assumed to be adequate
		3.1.3 S_Column_Concrete_1	Includes first/second/third floors plus the roof columns
		3.1.4 S_Column_Concrete_2	Includes first/second/third floors plus the roof columns
		3.1.5 W_Column_Concrete_1000	The following bay size calculation was used; =[(Bay size A)+(Bay size B)]/2 =[29.1+21.6]/2 =25 ft
		3.1.6 W_Column_Concrete_2000/3000/4000	The following bay size calculation was used; =[(Bay size A)+(Bay size B)]/2 =[29.1+21.6]/2 =25 ft
		3.1.7 W_Column_Concrete_5000	The following bay size calculation was used; =[(Bay size A)+(Bay size B)]/2 =[29.1+21.6]/2 =25 ft

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		3.1.8 W_Column_Concrete_Roof	The following bay size calculation was used; =[(Bay size A)+(Bay size B)]/2 =[29.1+21.6]/2 =25 ft
4.) Floors	Floors, much like in the columns section, in the Impact Estimator calculated the thickness of the material based on some basic variables regarding the assembly. The parameters were: floor width, span, concrete strength, concrete flyash content and live load. The assumptions that were required in this section were a live load of 75 psf, a concrete strength of 4000 psi and an average (9%) flyash content. For the west wing, a Double T concrete floor was used to model the floor structure and slab. A concrete topping was included on all Double T floors. The floor width was calculated by the following equation: =(Floor Area)/(Span)		
5.) Roofs	The roofs were modeled with concrete suspended slabs just like with the floors. The parameters were: roof width, span, concrete strength, concrete flyash content and live load. The assumptions that were required in this section were a live load of 75 psf, a concrete strength of 4000 psi and an average (9%) flyash content. To be able to account for the roofing envelope material being replaced during the renovation, the material was modelled separately in the Extra Basic Materials, section 6. The roof width was calculated by the following equation: =(Floor Area)/(Span)		
6.) Extra Basic Materials	Roofing envelope material was measured separately from the roof structure because only the envelope material is being replaced in renovations. The type of roofing material is known to be inverted 4ply built up asphalt roofing system on the south wing and was assumed to be the same on the west wing, since no roofing schedule was found. The specific materials within this system were chosen to be extruded polystyrene and glass felt. The thickness was estimated to be 4 inches for both the west and south wings.		

Table 14 Partial Demolition of Existing BioSciences Building Input Assumptions Document.

Partial Demolition of Existing BioSciences Building Input Assumptions Document			
Assembly Group	Assembly Type	Assembly Name (**S**:South Wing **W**:West Wing)	Specific Assumptions
1.)Walls	One major assumption for the west wing of the BioSciences building was that the 3000 level has the same floor plan as the 2000 level for the West Wing. The plans for the West Wing's 3000 level do not exist at UBC's Records Department. In modeling the respective wall types, the doors and windows were recorded with the exact wall they appeared in. Envelope and opening details were also gathered from numerous architectural drawings. A few assumptions and calculations were made in order to complete the modelling of the wall in Existing BioSciences Building, such as adjusting the length of the concrete in cast-in-place walls to accommodate wall thickness limitations in the Impact Estimator.		
	1.1 Concrete Block Wall		
		1.1.1 S_Concrete_BlockWall_SubBasement	Assume Rebar #4
		1.1.2 S_Concrete_BlockWall_Roof	Assume concrete block for brick Assume Rebar #4
		1.1.3 S_Concrete_BlockWall_Interior	Assume Rebar #4 Assume stucco (over porous surface) for plaster
		1.1.4 W_Concrete_BlockWall_0000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume Rebar #4
		1.1.5 W_Concrete_BlockWall_1000/2000/3000	Assume Rebar #4
	1.2 Steel Stud		
		1.2.1 S_SteelStud_ServiceStrip	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the south wings exterior walls were not being renovated, the windows where modelled in this service strip which is part of the renovations. The service strip therefore spans from the floor to the ceiling. Assume spacing is 16" o.c. Assume that window frames are fixed since only a small minority is operable.
		1.2.2 W_SteelStud_Interior_1000/2000/3000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume no sheathing since this is an interior wall Assume Light Gauge since this is an interior wall Assume spacing is 16" o.c. Assume moisture resistant gypsum

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
			plasterboard for use in laboratories
		1.2.3 W_SteelStud_Exterior_1000/2000/3000	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the west wings exterior walls were not being renovated, the windows where modelled with the interior portion of the wall which was renovated. Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume heavy gauge since this is an exterior wall Assume spacing is 16" o.c Assume windows frames are fixed since only a small minority is operable Assume reg gypsum board
		1.2.4 W_SteelStud_WindowWall_5000	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the west wings exterior walls were not being renovated, the windows where modelled with the interior portion of the wall labelled the window wall. The window wall therefore spans from the floor to the ceiling. Assume heavy gauge since this is an exterior wall Assume windows frames are fixed since only a small minority is operable Assume spacing is 16" o.c. Assume split faced brick for ceramic tile Assume reg gypsum board Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		1.2.5 W_SteelStud_ExteriorDoorWall_5000	Assume Light Gauge since this is an interior wall Assume spacing is 16" o.c.
		1.2.6 W_SteelStud_DoorWallReno_0000	Since this wall assembly is purely to model the doors that were replaced in the renovation, the steel studs and associated screw were backed out of the model. Through modeling this specific wall in the Impact Estimator the material were found as such: *0.0356 Tonnes Galvanized Stud* *0.0015 Tonnes Screw Nuts& Bolts* These values will be backed out in 2.) Extra Basic Materials

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
	1.3 Wood Stud		
		1.3.1 S_WoodStud_Pipe/DuctSpace	Assume Kiln Dried Assume 16" o.c.
		1.3.2 W_WoodStud_PartitionWall_1000	Assume Kiln Dried Assume 24" o.c. for partition wall
	1.4 Concrete Tilt Up		
		1.4.1 W_Concrete_TiltUp_Exterior_2000/3000	This wall was adjusted by a factor in order to fit one of the selections of either 6" of 8" thickness, for concrete tilt up walls, in Impact Estimator. In this case the wall was adjusted to a 6" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/6”] = (188ft)x[(4”)/6] = 125ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.4.2 W_Concrete_TiltUp_Exterior_4000	This wall was adjusted by a factor in order to fit one of the selections of either 6" of 8" thickness, for concrete tilt up walls, in Impact Estimator. In this case the wall was adjusted to a 6" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/6”] = (93ft)x[(4”)/6] = 62ft Assume concrete 4000 psi Assume FlyAsh%: Average
	1.5 Curtain Wall		
		1.5.1 W_CurtainWall_2000/3000	Percent viewable glazing was calculated from elevation drawing 065-06-066
		1.5.2 W_CurtainWall_4000	Percent viewable glazing was calculated from elevation drawing 065-06-066
2.) Extra Basic Materials	2.1 Roofing		
		Roofing materials were measured separately from roof structure because only the envelope material is being replaced in renovations. The type of roofing material is known to be inverted 4ply built up asphalt roofing system on the south wing and was assumed to be the same on the west wing, since no roofing schedule was found. The specific materials within this system were chosen to extruded polystyrene and glass felt. The thickness was estimated to be 4 inches for both the west and south wings.	

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
	2.2 Back Out		
		The back outs from all the wall assemblies above were accumulated to get the amount of galvanized steel studs and screw, nuts & bolts that aren't actually present in the building and therefore are required to be backed out of the Impact Estimator.	
	2.3 Cladding		
		Split faced brick cladding was used for the envelope of the exterior wall on the west wing's 5000 level. This material was replaced in the renovations but the wall assembly was not. Therefore the cladding was added separately in this demolition model. The equation to calculate the amount of brick was: =(Bricks/ft) x (Wall length) =(21) x (726ft) =15246 *Note. Bricks/ft factor was found by modeling a linear foot of W_SteelStud_Exterior_5000 wall in the Impact Estimator.	
	2.4 Polyethylene		
		6 mil polyethylene was added to all exterior walls as a vapour barrier in the building model. It was assumed that all the polyethylene was replaced in the renovations. Since none of the exterior walls were removed the polyethylene was added separately to this demolition model. The amount was taken from the Bill of Materials for the existing building. The value was 5125 m2	

Table 15 Partial Construction of New BioSciences Building Input Assumptions Document.

Partial Construction of New BioSciences Building Input Assumptions Document			
Assembly Group	Assembly Type	Assembly Name (**S:**South Wing **W:**West Wing)	Specific Assumptions
1.) Walls	In modeling the respective wall types, the doors and windows were recorded with the exact wall they appeared in. Envelope and opening details were also gathered from numerous architectural drawings.. Some assumption and calculations were required to model wall components that were replaced during renovations, such a doors and windows. In the Impact Estimator components such as doors and windows need to be attached to a wall assembly, but when the wall assembly isn't renovated, such as a concrete wall, what should be done? Our approach was to create specific window or door walls that would just house the specific door or window component. These walls were modeled as close to the height and width of the doors and windows as allowed in the Impact Estimator; however, the IE requires the walls to have a 10% larger area than that of the doors or windows. Therefore some back out calculations were required to remove the access materials that aren't actually present in the building. Some of the steel stud walls that were built in the renovations are substantially thinner the thinnest selection within the Impact Estimator. For instance, the steel studs used in the furring wall P19. The wall envelopes the concrete stair and elevator walls and has the furring specified at 22mm. A steel stud wall was used to model this in the IE but the thinnest steel stud selection is 92mm. Therefore a back out calculation was required to account for the access steel modeled that isn't actually present.		
	1.1 Concrete Cast in Place		
		1.1.1 S_Concrete_Cast-in-Place_SesmicWall_1000/2000/3000/4000	Assume Concrete: 30 MPa Assume FlyAsh%: Average
		1.1.2 S_Concrete_Cast-in-Place_SesmicWall_0000	Assume Concrete: 30 MPa Assume FlyAsh%: Average
		1.1.3 W_Concrete_Cast-in-Place_SesmicWall_1000/2000/3000/5000	Assume Concrete: 30 MPa Assume FlyAsh%: Average
		1.1.4 W_Concrete_Cast-in-Place_SesmicWall_4000	The height of this wall adjusted to allow the 5000 level seismic wall to be modeled at 3.81m. This was purely for ease of modeling, so that the 5000 level could be included with 1.1.3. Assume Concrete: 30 MPa Assume FlyAsh%: Average
		1.1.5 W_Concrete_Cast-in-Place_SesmicWall_0000	Assume that the seismic wall was built down to the level of the foundations. There was no access to the structural drawings so it was not clear that that is the case. Assume Concrete: 30 MPa Assume FlyAsh%: Average
		1.1.6 S_Concrete_Cast-in-Place_Tanks	Assume Concrete: 30 MPa Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is similar to an exterior wall
	1.2 Concrete Block Wall		

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.2.1 S_Concrete_BlockWall_P18/P28	Assume rebar 10M
		1.2.2 W_Concrete_BlockWall_P28	Assume rebar 10M
	1.3 Steel Stud		
		1.3.1 SteelStud_P4/P6/P7/P8/P21/P23/P24/P25	Assume Light Gauge steel stud, since this is an interior wall Assume Rockwool batt insulation for mineral wool batt Assume reg gypsum board for type "x" GWB
		1.3.2 W_SteelStud_WindowFrameWall_1000	Since this wall assembly is purely to model the windows that were replaced in the renovation, the steel studs and associated screws, nuts and bolts were backed out, out of the model. Through modeling this specific wall in the Impact Estimator the excess materials were found as such: *0.5487 Tonnes Galvanized Stud* *0.0567 Tonnes Screw Nuts& Bolts* These values will be backed out in 2.) Extra Materials Assume tin argon glazing for the unspecified argon glazing. (Argon glazing wasn't mentioned in the window assembly but was specified as such in the UBC BSC Energy Design Report)
		1.3.3 SteelStud_DoorWallReno	This wall was created to model the doors that were replaced in the renovation but the steel studs aren't backed out since there are actual wall sections surrounding the doors, in the corridor or hallway areas, where these doors mainly occurred. Assume Light Gauge steel stud, since this is an interior wall Assume spacing is 400mm o.c Assume 39 x 92 mm stud thickness
		1.3.4 W_SteelStud_DoorWallReno_0000	Since this wall assembly is purely to model the doors that were replaced in the renovation, the steel studs and associated screw, nuts and bolts were backed out, out of the model. Through modeling this specific wall in the Impact Estimator the materials were found as such: *0.0356 Tonnes Galvanized Stud* *0.0015 Tonnes Screw Nuts& Bolts* These values will be backed out in 2.) Extra Materials

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.3.5 SteelStud_P3/P5/P16	Assume Light Gauge since this is an interior wall Assume Rockwool batt insulation for mineral wool batt Assume reg gypsum board for type "x" GWB
		1.3.6 SteelStud_P19	Since this 39x22 mm furring wall was modeled using 39 x 92 mm steel stud a back out calculation was required to account for the excess steel that isn't actually present in the building. The back out factor was calculated as such: =(Galvanized Stud for 292m) x [1- (actual stud thickness)/(modeled thickness)] =(2.5882) x [1-(22mm)/(92mm)] *=1.9692 Tonnes Galvanized Stud* =(Screws Nuts& Bolts for 292m) x [1- (actual stud thickness)/(modeled thickness)] =(0.1504) x [1-(22mm)/(92mm)] *=0.1144 Tonnes Screws Nuts& Bolts* These values will be backed out in 2.) Extra Materials Assume Light Gauge steel stud, since this is an interior wall
		1.3.7 SteelStud_P17/P20	Since this 39x64 mm steel stud wall was modeled using 39 x 92 mm steel stud a back out calculation was required to account for the excess steel that isn't actually present in the building. The back out factor was calculated as such: =(Galvanized Stud for 113m) x [1- (actual stud thickness)/(modeled thickness)] =(0.9979) x [1-(64mm)/(92mm)] =0.3037 Tonnes Galvanized Stud =(Screws for 113m) x [1- (actual stud thickness)/(modeled thickness)] =(0.0582) x [1-(64mm)/(92mm)] =0.01771 Tonnes Screws Nuts& Bolts These values will be backed out in 2.) Extra Materials Assume Light Gauge steel stud, since this is an interior wall

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.3.8 SteelStud_W2/W3/W4/W5/W9/W11	Since this 39x64 mm steel stud wall was modeled using 39 x 92 mm steel stud a back out calculation was required to account for the excess steel that isn't actually present in the building. The back out factor was calculated as such: =(Galvanized Stud for 113m) x [1- (actual stud thickness)/(modeled thickness)] =(4.6926) x [1-(64mm)/(92mm)] *=1.4281 Tonnes Galvanized Stud* =(Screws for 113m) x [1- (actual stud thickness)/(modeled thickness)] =(0.2709) x [1-(64mm)/(92mm)] *=0.08244 Tonnes Screws Nuts& Bolt*s These values will be backed out in 2.) Extra Materials Assume Light Gauge since this is an interior wall Assume tin argon glazing for the unspecified argon glazing. (Argon glazing wasn't mentioned in the window assembly but was specified as such in the UBC BSC Energy Design Report) Assume expanded polystyrene for spray on foam insulation
		1.3.9 W_SteelStud_WindowWall_5000	Since this 39x64 mm steel stud wall was modeled using 39 x 92 mm steel stud a back out calculation was required to account for the excess steel that isn't actually present in the building. The back out factor was calculated as such: =(Galvanized Stud for 113m) x [1- (actual stud thickness)/(modeled thickness)] =(0.5668) x [1-(64mm)/(92mm)] *=0.1725 Tonnes Galvanized Stud* =(Screws for 113m) x [1- (actual stud thickness)/(modeled thickness)] =(0.0314) x [1-(64mm)/(92mm)] *=0.0956 Tonnes Screws Nuts& Bolt*s These values will be backed out in 2.) Extra Materials Assume Light Gauge since this is an interior wall Assume tin argon glazing for the unspecified argon glazing. (Argon glazing wasn't

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
			mentioned in the window assembly but was specified as such in the UBC BSC Energy Design Report) Assume expanded polystyrene for spray on foam insulation Assume commercial steel cladding for aluminum cladding
		1.3.10 SteelStud_P15_GlassWall	A steel stud wall was used to model this interior glass wall. The wall was modeled with one large window, to represent the glass assembly. To calculate the area of the window, the following calculations were completed: =[(length of wall)-(total cumulative door width)] x (Height of interior glass) =[348m-(0.6m x 64 Doors)] x 2.75m =852.5m2 However, within the Impact estimator, the door and window area has to less or equal to 90% of the total walls surface area. Therefore the window area had to be adjusted to 795m2 to account for this limitation. Assume Light Gauge steel stud, since this is an interior wall
		1.3.11 W_SteelStud_P10/P13	Assume Light Gauge steel stud, since this is an interior wall Assume Rockwool batt insulation for mineral wool batt
		1.3.12 S_SteelStud_P3/P15_0000	Assume Light Gauge steel stud, since this is an interior wall Assume Rockwool batt insulation for mineral wool batt
		1.3.13 S_SteelStud_P7_0000	Assume Light Gauge steel stud, since this is an interior wall Assume Rockwool batt insulation for mineral wool batt
	1.4 Curtain Wall		
		1.4.1 W_CurtainWall_Exterior_2000/3000	The height of this wall was adjusted 4.7m from 3.8m to account for the curtain wall that extends below the 2000 level and above the 3000 level. Percent viewable glazing was calculated from the west elevation drawing BSC A301 West Elevation.
2.) Extra Basic Materials	2.1 Roofing		

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		Since the roofing envelope was replaced during the renovation, the material had to be modeled separately from a roof structure assembly in the Impact Estimator. The specified roofing material was: 2 ply sbs high albedo membrane, barrier board, rigid insulation varying between 50-200mm thick and a vapour retarder. The closest selection of material in the Impact Estimator was Modified Bitumen Roofing system with extruded polystyrene + gypsum. The thickness was assumed to be 100mm to match the estimation for the Existing BioSciences Building’s roofing material thickness.	
	2.2 Hollow Structural Steel		
		Hollow structural steel was specified as 200 x 200 mm. It was assumed that the thickness was 8mm, since there wasn't any access to the structural drawings. It was found that 200 x 200 x8 mm member has a weight of 46.5 kg/m *ASTM A-500 http://www.bullmoosetube.com/_assets/10520.pdf The calculation to figure out how many tonnes of hollow structural steel is required is as follows: =(length) x (Weight factor) =(18m) x (46.5 kg/m) =837kg = 0.837 tonnes	
	2.3 Back Out		
		The back outs from all the wall assemblies above were accumulated to get the amount of galvanized steel studs and screw, nuts & bolts that aren't actually present in the building and therefore are required to be backed out of the Impact Estimator.	
	2.4 Cladding		
		Commercial (26 Ga) steel cladding was added to the W_SteelStud_Exterior_5000 wall to replace the split faced brick cladding on the existing building. Since this wall assembly wasn't replaced in the renovation, the steel cladding had to modeled separately. The actual wall assembly specified aluminum cladding, but the closest option within the Impact Estimator was commercial steel cladding. The amount of steel cladding required was calculated with the following equation: =(Cladding/m) x (Length of wall) =(11.2) x (221.3m) =2478.6m2 *Note: Cladding factor was calculated by modeling a linear meter of W_SteelStud_Exterior_5000 in the Impact Estimator.	
	2.5 Polyethylene		
		6 mil polyethylene was added to all exterior walls as a vapour barrier in the building model. It was assumed that all the polyethylene was replaced in the renovations. Since none of the exterior walls were removed the polyethylene was added separately to this renovation model. The amount was taken from the Bill of Materials for the Existing BioSciences Bbuilding. The value was 5125 m2	

Table 16 Full Construction of New BioSciences Building Input Assumptions Document.

Full Construction of New BioSciences Building Input Assumptions Document			
Assembly Group	Assembly Type	Assembly Name (**S**:South Wing **W**:West Wing)	Specific Assumptions
1.) Foundation	In the Impact Estimator, Slab-on-Grade inputs are limited to being either a 4" or 8" thickness. Since the actual SOG thickness for the Newly Built BioSciences Building was not exactly 4" or 8" thick, the areas measured were adjusted using a calculation to accommodate this limitation. Also the Impact Estimator limits the thickness of footings to be between 7.5" and 19.7" thick. As there are a number of cases where footing thicknesses exceed 19.7", the lengths of each footing were adjusted accordingly to maintain the same volume of concrete. Lastly, the concrete stairs were modelled as footings to be able to select the appropriate rebar specifications (i.e. Stairs_Concrete_TotalLength). An average stair thickness was applied to the total length of stairs measured in the building.		
	1.1 Concrete_Slab-on-Grade		
		1.1.1 S_Slab-on-Grade_Concrete_6"	The area of this slab had to be adjusted so that the thickness fit into the 4" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Slab Area) x (Actual Slab Thickness)) /(4"/12)] = sqrt[(6175' x (6"/12))/(4"/12)] = 96 ft Assume Concrete: 4000 psi Assume FlyAsh%: Average
		1.1.2 W_Slab-on-Grade_Concrete_6"	The area of this slab had to be adjusted so that the thickness fit into the 8" thickness specified in the Impact Estimator. The following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Slab Area) x (Actual Slab Thickness)) /(8"/12)] = sqrt[(9662' x (6"/12))/(8"/12)] = 85 ft Assume Concrete: 4000 psi Assume FlyAsh%: Average
	1.2 Concrete Footing		

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.2.1 S_Footing_Concrete_Strip_2'Wide	The length of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7". The thicknesses were set at 19" and the following calculation was done in order to determine appropriate length inputs for the footing; = (Volume of Concrete)/(Width)/(New Thickness) = (1399 ft3)/(2ft)/(19"x12) = 442 ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.2 S_Footing_Concrete_Strip_3'Wide	The length of this footing was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7". The thicknesses were set at 19" and the following calculation was done in order to determine appropriate length inputs for the footing; = (Volume of Concrete)/(Width)/(New Thickness) = (1209 ft3)/(3ft)/(19"x12) = 254.5 ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.3 S_Footing_Concrete_G	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7". The thicknesses were set at 19" and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness))/(19"/12)] = sqrt[(39ft2 x (26"/12))/(19"/12)] = 7.3ft Assume concrete 4000 psi Assume FlyAsh%: Average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.2.4 S_Footing_Concrete_A/B/C/D/E/F	The volume of these footing slabs were calculated since the thicknesses varied. Then the total volume of the footing was then divided by the set slab thickness of 19" to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7". This gave the area of the slab with a thickness of 19" from which the new Length and Width were determined; = sqrt[(Total Volume of Footings A/B/C/D/E/F)/(19"/12)] = sqrt[(3577ft3)/(19"/12)] = 47.5ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.5 S_Footing_Concrete_H	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7". The thicknesses were set at 19" and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness))/(19"/12)] = sqrt[(99ft2 x (32"/12))/(19"/12)] = 12.9ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.6 W_Footing_Concrete_16"Wide	Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.7 W_Footing_Concrete_18"Wide	Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.8 W_Footing_Concrete_24"Wide	Assume concrete 4000 psi Assume FlyAsh%: Average

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		1.2.9 W_Footing_Concrete_2'Thick	The area of this footing slab was adjusted to accommodate the Impact Estimator limitation of footing thicknesses to be under 19.7". The thicknesses were set at 19" and the following calculation was done in order to determine appropriate Length and Width (in feet) inputs for this slab; = sqrt[((Measured Footing Slab Area) x (Actual Slab Thickness))/(19"/12)] = sqrt[(2639ft2 x (32"/12))/(19"/12)] = 57.7ft Assume concrete 4000 psi Assume FlyAsh%: Average
		1.2.10 S_Stairs_Concrete	Thickness of the stairs were estimated to be 10" using measurement tool in On Screen TakeOff
		1.2.11 S_Stairs_Concrete_Landings	No assumption necessary
		1.2.12 W_Stairs_Concrete	No stair details could be found other then quite simple diagram on structural drawing 065-07-030. Stairs specification were taken from this drawing.
2.)Walls	One major assumption for the west wing of the Newly Built BioSciences Building was that the 3000 level has the same floor plan as the 2000 level for the West Wing. The plans for the West Wing's 3000 level of the Existing BioSciences Building (which the Newly Built BioSciences Building design was based on) do not exist at UBC's Records Department. In modeling the respective wall types, the doors and windows were recorded with the exact wall they appeared in. Envelope and opening details were also gathered from numerous architectural drawings. A few assumptions and calculations were made in order to complete the modelling of the wall in the Newly Built BioSciences building, such as adjusting the length of the concrete in cast-in-place walls to accommodate wall thickness limitations in the Impact Estimator.		
	2.1 Cast-in-Place		
		2.1.1 S_Concrete_Cast-in-Place_Foundation_1'Height	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12"] = (221 ft) x [(10")/12] = 184 ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		2.1.2 S_Concrete_Cast-in-Place_Foundation_10'8"Height	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12”] = (569ft)x[(10”)/12] = 474ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.1.3 S_Concrete_Cast-in-Place_Basement	This wall was adjusted by a factor in order to fit one of the selections of either 8" of12" thickness in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) * [(Cited Thickness)/12”] = (443ft)x[(10”)/12] = 396ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier
		2.1.4 S_Concrete_Cast-in-Place_Stair/Elevator	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12”] = (556ft)x[(10”)/12] = 463ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume Stucco (over a porous surface) instead of plaster

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		2.1.5 W_Concrete_Cast-in-Place_10"Thick	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12"] = (396ft)x[(10")/12] = 330ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier
		2.1.6 W_Concrete_Cast-in-Place_14"Thick	This wall was adjusted by a factor in order to fit one of the selections of either 8" of 12" thickness, for cast in place concrete walls, in Impact Estimator. In this case the wall was adjusted to a 12" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/12"] = (543ft)x[(14")/12] = 634ft Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.1.7 W_Concrete_Cast-in-Place_8"Thick	Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier
		2.1.8 W_Concrete_Cast-in-Place_Exterior_2000/3000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.1.9 W_Concrete_Cast-in-Place_Stairs/Elevator/ExteriorDetail	Assume concrete 4000 psi Assume FlyAsh%: Average Assume rebar #5
		2.1.10 W_Concrete_Cast-in-Place_Exterior_1000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
			since this is an exterior wall
		2.1.11 W_Concrete_Cast-in-Place_Exterior_5000	Assume concrete 4000 psi Assume FlyAsh%: Average Assume 6 mil polyethylene vapour barrier since this is an exterior wall
	2.2 Concrete Block Wall		
		2.2.1 S_Concrete_BlockWall_SubBasement	Assume Rebar #4
		2.2.2 S_Concrete_BlockWall_Roof	Assume concrete block for brick Assume Rebar #4
		2.2.3 S_Concrete_BlockWall_Exterior_3'6"Height	Assume Rebar #4 Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.2.4 S_Concrete_BlockWall_Exterior_7'Height	Assume Rebar #4 Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.2.5 S_Concrete_BlockWall_Interior	Assume Rebar #4 Assume stucco (over porous surface) for plaster
		2.2.6 W_Concrete_BlockWall_0000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume Rebar #4
		2.2.7 W_Concrete_BlockWall_1000/2000/3000	Assume Rebar #4
		2.2.8 W_Concrete_BlockWall_5000	Assume Rebar #4 Assume 6 mil polyethylene vapour barrier since this is an exterior wall
	2.3 Steel Stud		
		2.3.1 S_SteelStud_ServiceStrip	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the south wings exterior walls were not being renovated, the windows where modelled in this service strip which is part of the renovations. The service strip therefore spans from the floor to the ceiling. Assume spacing is 16" o.c. Assume that window frames are fixed since only a small minority is operable.
		2.3.2 W_SteelStud_Interior_1000/2000/3000	Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume no sheathing since this is an interior wall Assume Light Gauge since this is an interior wall Assume spacing is 16" o.c. Assume moisture resistant gypsum plasterboard for use in laboratories

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		2.3.3 W_SteelStud_Exterior_1000/2000/3000	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the west wings exterior walls were not being renovated, the windows where modelled with the interior portion of the wall which was renovated. Assume 3000 level floor plan is the same as 2000 level - missing 3000 level floor plan Assume heavy gauge since this is an exterior wall Assume spacing is 16" o.c Assume windows frames are fixed since only a small minority is operable Assume reg gypsum board
		2.3.4 W_SteelStud_WindowWall_5000	Windows that are to be replaced during renovations need to be part of a wall assembly in the Impact Estimator. Since the west wings exterior walls were not being renovated, the windows where modelled with the interior portion of the wall labelled the window wall. The window wall therefore spans from the floor to the ceiling. Assume heavy gauge since this is an exterior wall Assume windows frames are fixed since only a small minority is operable Assume spacing is 16" o.c. Assume split faced brick for ceramic tile Assume reg gypsum board Assume 6 mil polyethylene vapour barrier since this is an exterior wall
		2.3.5 W_SteelStud_ExteriorDoorWall_5000	Assume Light Gauge since this is an interior wall Assume spacing is 16" o.c.
		2.3.6 W_SteelStud_Exterior_5000	Assume heavy gauge since this is an exterior wall Assume spacing is 16" o.c Assume split faced brick for ceramic tile Assume 6 mil polyethylene vapour barrier since this is an exterior wall
	2.4 Wood Stud		
		2.4.1 S_WoodStud_Pipe/DuctSpace	Assume Kiln Dried Assume 16" o.c.
		2.4.2 W_WoodStud_PartitionWall_1000	Assume Kiln Dried Assume 24" o.c. for partition wall
	2.5 Concrete Tilt Up		

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		2.5.1 W_Concrete_TiltUp_Exterior_2000/3000	This wall was adjusted by a factor in order to fit one of the selections of either 6" of 8" thickness, for concrete tilt up walls, in Impact Estimator. In this case the wall was adjusted to a 6" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/6”] = (1022ft)x[(4”)/6] = 681ft Assume concrete 4000 psi Assume FlyAsh%: Average
		2.5.2 W_Concrete_TiltUp_Exterior_4000	This wall was adjusted by a factor in order to fit one of the selections of either 6" of 8" thickness, for concrete tilt up walls, in Impact Estimator. In this case the wall was adjusted to a 6" thickness. This was done by decreasing the length of the wall using the following equation; = (Measured Length) x [(Cited Thickness)/6”] = (540ft)x[(4”)/6] = 360ft Assume concrete 4000 psi Assume FlyAsh%: Average
		2.5.3 W_Concrete_TiltUp_Railing_5000	Assume concrete 4000 psi Assume FlyAsh%: Average
	2.6 Curtain Wall		
		2.6.1 W_CurtainWall_2000/3000	Percent viewable glazing was calculated from elevation drawing 065-06-066
		2.6.2 W_CurtainWall_4000	Percent viewable glazing was calculated from elevation drawing 065-06-066
3.) Columns	The method used to measure column sizing was completely depended upon the metrics built into the Impact Estimator. That is, the Impact Estimator calculates the sizing of beams and columns based on the following inputs; number of beams, number of columns, floor to floor height, bay size, supported span and live load. This being the case, beams (only for the south wing) and concrete columns were counted on each floor and each associated floor area was measured. Since this is an institutional building the live loading was assumed to be 75 psf.		
	3.1 Concrete Columns		
		3.1.1 S_Column_Concrete_Basement_1	Column plan for the basement level was not able to be found so the column plan for the first floor was assumed to be adequate
		3.1.2 S_Column_Concrete_Basement_2	Column plan for the basement level was not able to be found so the column plan for the first floor was assumed to be adequate

Assembly Group	Assembly Type	Assembly Name (S:South Wing W:West Wing)	Specific Assumptions
		3.1.3 S_Column_Concrete_1	Includes first/second/third floors plus the roof columns
		3.1.4 S_Column_Concrete_2	Includes first/second/third floors plus the roof columns
		3.1.5 W_Column_Concrete_1000	The following bay size calculation was used; =[(Bay size A)+(Bay size B)]/2 =[29.1+21.6]/2 =25 ft
		3.1.6 W_Column_Concrete_2000/3000/4000	The following bay size calculation was used; =[(Bay size A)+(Bay size B)]/2 =[29.1+21.6]/2 =25 ft
		3.1.7 W_Column_Concrete_5000	The following bay size calculation was used; =[(Bay size A)+(Bay size B)]/2 =[29.1+21.6]/2 =25 ft
		3.1.8 W_Column_Concrete_Roof	The following bay size calculation was used; =[(Bay size A)+(Bay size B)]/2 =[29.1+21.6]/2 =25 ft
4.) Floors	Floors, much like in the columns section, in the Impact Estimator are calculated based on the thickness and a few other assembly parameters including; floor width, span, concrete strength, concrete flyash content and live load. The assumptions that were required in this section included a live load of 75 psf, concrete strength of 4000 psi and average (9%) flyash content. For the west wing, a Double T concrete floor was used to model the floor structure and slab. A concrete topping was included on all Double T floors. The floor width was calculated by the following equation: =(Floor Area)/(Span)		
5.) Roofs	The roofs of the wings were modeled with concrete suspended slabs, which require defining similar parameters to the floors. The parameters were: roof width, span, concrete strength, concrete flyash content and live load. The assumptions that were required in this section included a live load of 75 psf, concrete strength of 4000 psi and average (9%) flyash content. To be able to account for the roofing envelope material being replaced during the renovation, the material was modelled separately in the Extra Basic Materials, section 6. The roof width was calculated by the following equation: =(Floor Area)/(Span)		

<table>
<tr><th>Assembly Group</th><th>Assembly Type</th><th>Assembly Name
(S:South Wing W:West Wing)</th><th>Specific Assumptions</th></tr>
<tr><td>6.) Extra Basic Materials</td><td colspan="3">Since the roofing envelope was replaced during the renovation, the material had to modeled separately from a roof structure assembly in the Impact Estimator. The material selected for the new construction was identical to the material applied for the renovations. This was an assumption that if the building was to be reconstructed today it would use a very similar, if not identical, roofing envelope as specified for the renovated building.

The specified roofing material was: 2 ply sbs high albedo membrane, barrier board, rigid insulation varying between 50-200mm thick and a vapour retarder. The closest selection of material in the Impact Estimator was Modified Bitumen Roofing system with extruded polystyrene + gypsum. The thickness was assumed to be 100mm to match the estimation for the Existing BioSciences Building's roofing material thickness.</td></tr>
</table>

Appendix D Inventory Analysis Result Details

Table 17 Bill of Materials occurring in Renovating scenario.

Construction Product	Unit	Existing BioSciences Building	Partial Demolition of Existing BioSciences Building	Salvaged BioSciences Building	Partial Construction of New BioSciences Building	Renovated New BioSciences Building
		Bill of Materials Existing	Bill of Materials Removed	Bill of Materials Salvaged	Bill of Materials New	Bill of Materials Final
#15 Organic Felt	m2	51,366	51,366	0	27,801	27,801
1/2" Moisture Resistant Gypsum Board	m2				3,235	3,235
1/2" Regular Gypsum Board	m2	66	66	0		0
5/8" Fire-Rated Type X Gypsum Board	m2				1,258	1,258
5/8" Moisture Resistant Gypsum Board	m2	890	161	729	366	1,095
5/8" Regular Gypsum Board	m2	8,691	8,691	0	9,387	9,387
6 mil Polyethylene	m2	5,125	5,115	10	10,523	10,533
Aluminum	Tonnes	13	10	4	14	17
Ballast (aggregate stone)	kg	679,548	679,548	0		0
Batt. Fiberglass	m2 (25mm)	2,911	2,062	849		849
Batt. Rockwool	m2 (25mm)				32,262	32,262
Cold Rolled Sheet	Tonnes	0	0	0		0
Commercial(26 ga.) Steel Cladding	m2				3,614	3,614
Concrete 30 MPa (flyash av)	m3	4,255	27	4,228	504	4,732
Concrete 60 MPa (flyash av)	m3	537	0	537		537
Concrete Blocks	Blocks	64,955	54,144	10,811	3,460	14,271
EPDM membrane (black, 60 mil)	kg	633	583	50	640	690
Expanded Polystyrene	m2 (25mm)	13	13	0	2,705	2,705
Extruded Polystyrene	m2 (25mm)	16,112	13,099	3,012	11,615	14,627
Galvanized Sheet	Tonnes	5	4	1	20	21
Galvanized Studs	Tonnes	43	40	3	39	42
Glazing Panel	Tonnes	9	2	7	11	18
Hollow Structural Steel	Tonnes				1	1
Joint Compound	Tonnes	10	9	1	11	12
Low E Tin Argon Filled Glazing	m2				603	603
Modified Bitumen membrane	kg	1,458	1,440	19	101,204	101,222
Mortar	m3	1,343	1,046	297	66	363
Nails	Tonnes	2	1	0	3	3
Ontario (Standard) Brick	m2	1,240	0	1,240		1,240
Paper Tape	Tonnes	0	0	0	0	0
Polyethylene Filter Fabric	Tonnes	1	1	0		0
Rebar, Rod, Light Sections	Tonnes	558	155	403	24	427
Roofing Asphalt	kg	45,743	45,743	0	49,471	49,471
Screws Nuts & Bolts	Tonnes	2	2	0	2	3
Small Dimension Softwood Lumber, kiln-dried	m3	26	26	0	5	5
Softwood Plywood	m2 (9mm)	3,182	2,256	926		926

Table 15 cont'd.

Construction Product	Unit	Existing BioSciences Building Bill of Materials Existing	Partial Demolition of Existing BioSciences Building Bill of Materials Removed	Salvaged BioSciences Building Bill of Materials Salvaged	Partial Construction of New BioSciences Building Bill of Materials New	Renovated New BioSciences Building Bill of Materials Final
Solvent Based Alkyd Paint	L	6	6	1	87	87
Split-faced Concrete Block	Blocks	19,674	19,491	184		184
Standard Glazing	m2	749	749	0	880	880
Stucco over porous surface	m2	4,978	3,543	1,435		1,435
Water Based Latex Paint	L	711	557	154	54	208
Welded Wire Mesh / Ladder Wire	Tonnes	8	0	8		8

Table 18 Bill of Materials occurring in Building New scenario

Construction Product	Unit	Existing BioSciences Building Bill of Materials Existing	Full Demolition of Existing BioSciences Building Bill of Materials Removed	Salvaged BioSciences Building Bill of Materials Salvaged	Full Construction of New BioSciences Building Bill of Materials New	Newly Built New BioSciences Building Bill of Materials Final
#15 Organic Felt	m2	51,366	51,366		27,867	27,867
1/2" Moisture Resistant Gypsum Board	m2					
1/2" Regular Gypsum Board	m2	66	66		8,506	8,506
5/8" Fire-Rated Type X Gypsum Board	m2					
5/8" Moisture Resistant Gypsum Board	m2	890	890		1,857	1,857
5/8" Regular Gypsum Board	m2	8,691	8,691		5,628	5,628
6 mil Polyethylene	m2	5,125	5,125		15	15
Aluminum	Tonnes	13	13			
Ballast (aggregate stone)	kg	679,548	679,548		3,392	3,392
Batt. Fiberglass	m2 (25mm)	2,911	2,911		0	0
Batt. Rockwool	m2 (25mm)					
Cold Rolled Sheet	Tonnes	0	0		4,009	4,009
Commercial(26 ga.) Steel Cladding	m2					
Concrete 30 MPa (flyash av)	m3	4,255	4,255		891	891
Concrete 60 MPa (flyash av)	m3	537	537		68,378	68,378
Concrete Blocks	Blocks	64,955	64,955		657	657
EPDM membrane (black, 60 mil)	kg	633	633		13	13
Expanded Polystyrene	m2 (25mm)	13	13		6,032	6,032
Extruded Polystyrene	m2 (25mm)	16,112	16,112		11,618	11,618
Galvanized Sheet	Tonnes	5	5		47	47
Galvanized Studs	Tonnes	43	43		12	12
Glazing Panel	Tonnes	9	9		10	10
Hollow Structural Steel	Tonnes					
Joint Compound	Tonnes	10	10		2,008	2,008
Low E Tin Argon Filled Glazing	m2					
Modified Bitumen membrane	kg	1,458	1,458		102,638	102,638
Mortar	m3	1,343	1,343		2	2
Nails	Tonnes	2	2		1,261	1,261
Ontario (Standard) Brick	m2	1,240	1,240		0	0
Paper Tape	Tonnes	0	0			
Polyethylene Filter Fabric	Tonnes	1	1		574	574
Rebar, Rod, Light Sections	Tonnes	558	558		22	22
Roofing Asphalt	kg	45,743	45,743		49,473	49,473
Screws Nuts & Bolts	Tonnes	2	2		28	28
Small Dimension Softwood Lumber, kiln-dried	m3	26	26		3,752	3,752
Softwood Plywood	m2 (9mm)	3,182	3,182		6	6
Solvent Based Alkyd Paint	L	6	6		27,092	27,092

Table 16 cont'd.

Construction Product	Unit	Existing BioSciences Building Bill of Materials Existing	Full Demolition of Existing BioSciences Building Bill of Materials Removed	Salvaged BioSciences Building Bill of Materials Salvaged	Full Construction of New BioSciences Building Bill of Materials New	Newly Built New BioSciences Building Bill of Materials Final
Split-faced Concrete Block	Blocks	19,674	19,674		749	749
Standard Glazing	m2	749	749		5,227	5,227
Stucco over porous surface	m2	4,978	4,978		738	738
Water Based Latex Paint	L	711	711		8	8
Welded Wire Mesh / Ladder Wire	Tonnes	8	8			

Table 19 Bill of Materials in Building New scenario for the Full Construction of new BioSciences Building.

Material	Unit	Bill of Materials - Full Construction of new BioSciences Building					
		Foundation	Walls	Floors	Columns & Beams	Roof	Total
#15 Organic Felt	m2					27,801	27,801
1/2" Moisture Resistant Gypsum Board	m2					3,235	3,235
1/2" Regular Gypsum Board	m2		66				66
5/8" Fire-Rated Type X Gypsum Board	m2						
5/8" Moisture Resistant Gypsum Board	m2		8,506				8,506
5/8" Regular Gypsum Board	m2		1,857				1,857
6 mil Polyethylene	m2		5,628				5,628
Aluminum	Tonnes		15				15
Ballast (aggregate stone)	kg						
Batt. Fiberglass	m2 (25mm)		3,392				3,392
Batt. Rockwool	m2 (25mm)						
Cold Rolled Sheet	Tonnes		0				0
Commercial(26 ga.) Steel Cladding	m2						
Concrete 30 MPa (flyash av)	m3	706	1,491	1,075	737	354	4,364
Concrete 60 MPa (flyash av)	m3			537			537
Concrete Blocks	Blocks		68,378				68,378
EPDM membrane (black, 60 mil)	kg		657				657
Expanded Polystyrene	m2 (25mm)		13				13
Extruded Polystyrene	m2 (25mm)		6,032			11,615	17,647
Galvanized Sheet	Tonnes		3			1	4
Galvanized Studs	Tonnes		46				46
Glazing Panel	Tonnes		12				12
Hollow Structural Steel	Tonnes						
Joint Compound	Tonnes		10				10
Low E Tin Argon Filled Glazing	m2						
Modified Bitumen membrane	kg		2,008			101,204	103,212
Mortar	m3		1,435				1,435
Nails	Tonnes		2			1	3
Ontario (Standard) Brick	m2		1,260				1,260
Paper Tape	Tonnes		0				0
Polyethylene Filter Fabric	Tonnes						
Rebar, Rod, Light Sections	Tonnes	3	237	63	271	22	597
Roofing Asphalt	kg					49,471	49,471
Screws Nuts & Bolts	Tonnes		2				2

Table 17 cont'd.

Material	Unit	Bill of Materials - Full Construction of new BioSciences Building					
		Foundation	Walls	Floors	Columns & Beams	Roof	Total
Small Dimension Softwood Lumber, kiln-dried	m3		28				28
Softwood Plywood	m2 (9mm)		3,752				3,752
Solvent Based Alkyd Paint	L		6				6
Split-faced Concrete Block	Blocks		27,092				27,092
Standard Glazing	m2		749				749
Stucco over porous surface	m2		5,227				5,227
Water Based Latex Paint	L		738				738
Welded Wire Mesh / Ladder Wire	Tonnes	1		6			8

Table 20 Bill of Materials in Renovating scenario for the Partial Construction of New BioSciences Building.

Material	Unit	Bill of Materials - Partial Construction of new BioSciences Building					
		Foundation	Walls	Floors	Columns & Beams	Roof	Total
#15 Organic Felt	m2					27,801	27,801
1/2" Moisture Resistant Gypsum Board	m2					3,235	3,235
1/2" Regular Gypsum Board	m2						
5/8" Fire-Rated Type X Gypsum Board	m2		1,258				1,258
5/8" Moisture Resistant Gypsum Board	m2		366				366
5/8" Regular Gypsum Board	m2		9,387				9,387
6 mil Polyethylene	m2		5,295			5,228	10,523
Aluminum	Tonnes		14				14
Ballast (aggregate stone)	kg						
Batt. Fiberglass	m2 (25mm)						
Batt. Rockwool	m2 (25mm)		32,262				32,262
Cold Rolled Sheet	Tonnes						
Commercial(26 ga.) Steel Cladding	m2		2,813			802	3,614
Concrete 30 MPa (flyash av)	m3		504				504
Concrete 60 MPa (flyash av)	m3						
Concrete Blocks	Blocks		3,460				3,460
EPDM membrane (black, 60 mil)	kg		640				640
Expanded Polystyrene	m2 (25mm)		2,705				2,705
Extruded Polystyrene	m2 (25mm)					11,615	11,615
Galvanized Sheet	Tonnes		19			1	20
Galvanized Studs	Tonnes		39				39
Glazing Panel	Tonnes		11				11
Hollow Structural Steel	Tonnes	1					1
Joint Compound	Tonnes		11				11
Low E Tin Argon Filled Glazing	m2		603				603
Modified Bitumen membrane	kg					101,204	101,204
Mortar	m3		66				66
Nails	Tonnes		2			1	3
Ontario (Standard) Brick	m2						
Paper Tape	Tonnes		0				0
Polyethylene Filter Fabric	Tonnes						
Rebar, Rod, Light Sections	Tonnes		24				24
Roofing Asphalt	kg					49,471	49,471
Screws Nuts & Bolts	Tonnes		2				2

Table 18 cont'd.

Material	Unit	Bill of Materials - Partial Construction of new BioSciences Building					
		Foundation	Walls	Floors	Columns & Beams	Roof	Total
Small Dimension Softwood Lumber, kiln-dried	m3		5				5
Softwood Plywood	m2 (9mm)						
Solvent Based Alkyd Paint	L		87				87
Split-faced Concrete Block	Blocks						
Standard Glazing	m2		880				880
Stucco over porous surface	m2						
Water Based Latex Paint	L		54				54
Welded Wire Mesh / Ladder Wire	Tonnes						

Table 21 Resources Use inputs into Manufacturing of Construction Products and Partial Construction of Renovated New BioSciences Building.

Resource	Units	Assembly Groups - Renovated New BioSciences Building										
		Foundations		Walls		Floors		Columns & Beams		Roof		Total Resource Use Result
		Man.	Const.	Man.	Const.	Man.	Const.	Man.	Const.	Man.	Const.	
Limestone	tonnes	0	-	267	-	-	-	-	-	20	-	286
Clay & Shale	tonnes	-	-	63	-	-	-	-	-	0	-	63
Iron Ore	tonnes	1	-	62	-	-	-	-	-	5	-	68
Sand	tonnes	-	-	47	-	-	-	-	-	0	-	47
Ash	tonnes	-	-	2	-	-	-	-	-	0	-	2
Gypsum	tonnes	-	-	111	-	-	-	-	-	27	-	138
Semi-Cementitious Material	tonnes	-	-	16	-	-	-	-	-	-	-	16
Coarse Aggregate	tonnes	-	-	550	-	-	-	-	-	-	-	550
Fine Aggregate	tonnes	-	-	416	-	-	-	-	-	-	-	416
Water	L	2	-	5,549	-	-	-	-	-	480	-	6,032
Obsolete Scrap Steel	tonnes	1	-	39	-	-	-	-	-	2	-	42
Coal	tonnes	0	0	92	0	-	-	-	-	13	0	105
Wood Fiber	tonnes	-	-	3	-	-	-	-	-	0	-	3
Uranium	tonnes	0	0	0	0	-	-	-	-	0	0	0
Natural Gas	m3	0	0	65	0	-	-	-	-	38	0	104
Natural Gas as feedstock	m3	-	-	3	-	-	-	-	-	23	-	27
Crude Oil	L	0	0	27	10	-	-	-	-	71	2	110
Crude Oil as feedstock	L	-	-	2	-	-	-	-	-	150	-	152
Metallurgical Coal as feedstock	tonnes	-	-	24	-	-	-	-	-	2	-	26
Prompt Scrap Steel as feedstock	tonnes	0	-	24	-	-	-	-	-	1	-	26

Table 22 Resources Use inputs into Manufacturing of Construction Products and Full Construction of Newly Built BioSciences Building.

Resource	Units	Assembly Groups - Newly Built BioSciences Building										
		Foundations		Walls		Floors		Columns & Beams		Roof		Total Resource Use Result
		Man.	Const.	Man.	Const.	Man.	Const.	Man.	Const.	Man.	Const.	
Limestone	tonnes	264	-	1,190	-	629	-	1,190	-	154	-	3,426
Clay & Shale	tonnes	72	-	484	-	170	-	484	-	36	-	1,247
Iron Ore	tonnes	8	-	63	-	20	-	63	-	5	-	159
Sand	tonnes	16	-	93	-	37	-	93	-	8	-	248
Ash	tonnes	2	-	10	-	5	-	10	-	1	-	28
Gypsum	tonnes	0	-	111	-	0	-	111	-	27	-	249
Semi-Cementitious Material	tonnes	22	-	46	-	51	-	46	-	11	-	176
Coarse Aggregate	tonnes	771	-	1,768	-	1,759	-	1,768	-	387	-	6,453
Fine Aggregate	tonnes	509	-	2,585	-	1,178	-	2,585	-	256	-	7,112
Water	L	361,819	-	6,243,143	-	1,403,137	-	6,243,143	-	417,598	-	14,668,839
Obsolete Scrap Steel	tonnes	3	-	168	-	44	-	168	-	15	-	398
Coal	tonnes	18	0	117	0	44	0	117	0	14	0	311
Wood Fiber	tonnes	-	-	38	-	-	-	38	-	-	-	76
Uranium	tonnes	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	m3	18,298	120	195,279	1,094	53,475	279	195,279	1,094	49,053	114	514,086
Natural Gas as feedstock	m3	-	-	4,787	-	-	-	4,787	-	22,042	-	31,617
Crude Oil	L	6,936	4,940	52,585	37,270	17,108	20,163	52,585	37,270	73,969	4,912	307,738
Crude Oil as feedstock	L	-	-	8,080	-	-	-	8,080	-	149,593	-	165,752
Metallurgical Coal as feedstock	tonnes	-	-	14	-	-	-	14	-	0	-	29
Prompt Scrap Steel as feedstock	tonnes	2	-	107	-	28	-	107	-	10	-	254

Appendix E Impact Assessment Result Details

Table 23 Renovating Scenario impact assessment results by life cycle stage.

Impact Category	Category Indicator	Renovating Scenario Life Cycle Stages									
		Partial Demolition Existing Building			Manufacturing New Materials			Partial Construction New Building			Total Impact Assessment Result
		Material	Transpor-tation	Total	Material	Transpor-tation	Total	Material	Transpor-tation	Total	
Fossil Fuel Consumption	MJ	6.1E+06	1.8E+05	**6.2E+06**	1.8E+07	1.8E+05	**1.8E+07**	1.3E+05	3.4E+05	**4.6E+05**	**2.5E+07**
Weighted Resource Use	kg	1.4E+05	4.2E+03	**1.5E+05**	2.5E+06	6.1E+03	**2.5E+06**	2.9E+03	7.9E+03	**1.1E+04**	**2.7E+06**
Global Warming Potential	kg CO_2 eq	4.0E+05	1.3E+04	**4.1E+05**	9.8E+05	1.4E+04	**9.9E+05**	9.7E+03	2.0E+04	**2.9E+04**	**1.4E+06**
Acidification Potential	moles of H^+ eq	2.2E+04	4.2E+03	**2.6E+04**	6.2E+05	5.8E+03	**6.3E+05**	5.0E+03	7.7E+03	**1.3E+04**	**6.7E+05**
HH Respiratory Effects Potential	kg $PM_{2.5}$ eq	2.1E+01	5.1E+00	**2.6E+01**	5.2E+03	7.0E+00	**5.2E+03**	5.6E+00	9.3E+00	**1.5E+01**	**5.2E+03**
Eutrophication Potential	kg N eq	1.5E+01	4.0E+00	**1.9E+01**	3.8E+02	6.1E+00	**3.8E+02**	4.6E+00	8.0E+00	**1.3E+01**	**4.1E+02**
Ozone Depletion Potential	kg CFC^{-11} eq	1.8E-05	5.5E-07	**1.8E-05**	1.9E-03	5.8E-07	**1.9E-03**	6.0E-10	8.2E-07	**8.2E-07**	**1.9E-03**
Smog Potential	kg NOx eq	2.8E+02	9.4E+01	**3.8E+02**	6.8E+03	1.3E+02	**6.9E+03**	1.1E+02	1.7E+02	**2.9E+02**	**7.6E+03**

Table 24 Building New Scenario impact assessment results by life cycle stage.

Impact Category	Category Indicator	Building New Scenario Life Cycle Stages									
		Full Demolition Existing Building			Manufacturing New Materials			Full Construction New Building			Total Impact Assessment Result
		Material	Transpor-tation	Total	Material	Transpor-tation	Total	Material	Transpor-tation	Total	
Fossil Fuel Consumption	MJ	7.9E+06	6.1E+05	**8.5E+06**	3.6E+07	8.9E+05	**3.7E+07**	1.1E+06	1.6E+06	**2.8E+06**	**4.8E+07**
Weighted Resource Use	kg	1.8E+05	1.4E+04	**2.0E+05**	1.8E+07	2.7E+04	**1.8E+07**	2.6E+04	3.9E+04	**6.5E+04**	**1.8E+07**
Global Warming Potential	kg CO_2 eq	5.1E+05	4.6E+04	**5.6E+05**	3.0E+06	6.8E+04	**3.0E+06**	7.9E+04	1.2E+05	**2.0E+05**	**3.8E+06**
Acidification Potential	moles of H^+ eq	2.8E+04	1.4E+04	**4.3E+04**	1.4E+06	2.8E+04	**1.4E+06**	4.2E+04	3.9E+04	**8.1E+04**	**1.5E+06**
HH Respiratory Effects Potential	kg $PM_{2.5}$ eq	2.7E+01	1.7E+01	**4.4E+01**	9.2E+03	3.4E+01	**9.2E+03**	4.7E+01	4.6E+01	**9.3E+01**	**9.3E+03**
Eutrophication Potential	kg N eq	1.9E+01	1.4E+01	**3.3E+01**	1.5E+03	2.9E+01	**1.5E+03**	4.1E+01	4.0E+01	**8.1E+01**	**1.6E+03**
Ozone Depletion Potential	kg CFC^{-11} eq	2.3E-05	1.9E-06	**2.5E-05**	4.3E-03	2.8E-06	**4.3E-03**	5.9E-10	4.9E-06	**4.9E-06**	**4.3E-03**
Smog Potential	kg NOx eq	3.6E+02	3.2E+02	**6.9E+02**	1.5E+04	6.4E+02	**1.6E+04**	1.4E+03	8.6E+02	**2.2E+03**	**1.9E+04**

Table 25 Renovating scenario impact assessment results by assembly group and life cycle stage.

			Renovating Scenario Life Cycle Stages										
			Partial Demolition Existing Building			Manufacturing New Materials			Partial Construction New Building				
Impact Category	Assembly Group	Category Indicator	Material	Transportation	Total	Material	Transportation	Total	Material	Transportation	Total	Assembly Group Total	Total Impact Assessment Result
Fossil Fuel Consumption	Foundations	MJ				2.30E+04	2.16E+02	**2.32E+04**	0.00E+00	9.16E+02	**9.16E+02**	**2.41E+04**	
	Walls	MJ				6.33E+06	1.57E+05	**6.48E+06**	1.27E+05	2.84E+05	**4.11E+05**	**6.89E+06**	
	Floors	MJ				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Columns & Beams	MJ				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Roof	MJ				1.13E+07	2.64E+04	**1.13E+07**	0.00E+00	5.15E+04	**5.15E+04**	**1.14E+07**	
	Process Total	**MJ**	**6.07E+06**	**1.79E+05**	**6.25E+06**	**1.77E+07**	**1.83E+05**	**1.78E+07**	**1.27E+05**	**3.37E+05**	**4.63E+05**		
	Total IA Result	**MJ**											**2.45E+07**
Weighted Resource Use	Foundations	kg				3.59E+03	8.73E+00	**3.60E+03**	0.00E+00	2.13E+01	**2.13E+01**	**3.62E+03**	
	Walls	kg				2.20E+06	5.24E+03	**2.21E+06**	2.94E+03	6.67E+03	**9.61E+03**	**2.22E+06**	
	Floors	kg				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Columns & Beams	kg				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Roof	kg				3.29E+05	8.20E+02	**3.30E+05**	0.00E+00	1.21E+03	**1.21E+03**	**3.31E+05**	
	Process Total	**kg**	**1.43E+05**	**4.21E+03**	**1.47E+05**	**2.53E+06**	**6.07E+03**	**2.54E+06**	**2.94E+03**	**7.91E+03**	**1.08E+04**		
	Total IA Result	**kg**											**2.70E+06**
Global Warming Potential	Foundations	kg CO2 eq				1.09E+03	1.82E+01	**1.11E+03**	0.00E+00	1.85E+01	**1.85E+01**	**1.13E+03**	
	Walls	kg CO2 eq				6.27E+05	1.19E+04	**6.39E+05**	9.69E+03	1.60E+04	**2.57E+04**	**6.65E+05**	
	Floors	kg CO2 eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Columns & Beams	kg CO2 eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Roof	kg CO2 eq				3.48E+05	1.94E+03	**3.50E+05**	0.00E+00	3.80E+03	**3.80E+03**	**3.54E+05**	
	Process Total	**kg CO2 eq**	**3.96E+05**	**1.34E+04**	**4.09E+05**	**9.77E+05**	**1.38E+04**	**9.90E+05**	**9.69E+03**	**1.98E+04**	**2.95E+04**		
	Total IA Result	**kg CO2 eq**											**1.43E+06**
Acidification Potential	Foundations	moles of H+ eq				4.80E+02	7.70E+00	**4.88E+02**	0.00E+00	1.89E+01	**1.89E+01**	**5.07E+02**	
	Walls	moles of H+ eq				4.33E+05	5.01E+03	**4.38E+05**	5.01E+03	6.42E+03	**1.14E+04**	**4.49E+05**	
	Floors	moles of H+ eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Columns & Beams	moles of H+ eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Roof	moles of H+ eq				1.89E+05	7.57E+02	**1.90E+05**	0.00E+00	1.21E+03	**1.21E+03**	**1.91E+05**	
	Process Total	**moles of H+ eq**	**2.19E+04**	**4.22E+03**	**2.62E+04**	**6.22E+05**	**5.77E+03**	**6.28E+05**	**5.01E+03**	**7.66E+03**	**1.27E+04**		
	Total IA Result	**moles of H+ eq**											**6.67E+05**
Human Health Respiratory Effects Potential	Foundations	kg PM2.5 eq				2.51E+00	9.36E-03	**2.52E+00**	0.00E+00	2.34E-02	**2.34E-02**	**2.54E+00**	
	Walls	kg PM2.5 eq				4.26E+03	6.09E+00	**4.27E+03**	5.57E+00	7.79E+00	**1.34E+01**	**4.28E+03**	
	Floors	kg PM2.5 eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Columns & Beams	kg PM2.5 eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Roof	kg PM2.5 eq				9.25E+02	9.17E-01	**9.26E+02**	0.00E+00	1.46E+00	**1.46E+00**	**9.28E+02**	
	Process Total	**kg PM2.5 eq**	**2.09E+01**	**5.07E+00**	**2.60E+01**	**5.19E+03**	**7.01E+00**	**5.20E+03**	**5.57E+00**	**9.27E+00**	**1.48E+01**		
	Total IA Result	**kg PM2.5 eq**											**5.24E+03**
Eutrophication Potential	Foundations	kg N eq				7.14E-01	8.11E-03	**7.22E-01**	0.00E+00	2.05E-02	**2.05E-02**	**7.42E-01**	
	Walls	kg N eq				3.15E+02	5.28E+00	**3.20E+02**	4.56E+00	6.75E+00	**1.13E+01**	**3.32E+02**	
	Floors	kg N eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Columns & Beams	kg N eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Roof	kg N eq				5.97E+01	7.94E-01	**6.05E+01**	0.00E+00	1.26E+00	**1.26E+00**	**6.17E+01**	
	Process Total	**kg N eq**	**1.51E+01**	**3.99E+00**	**1.91E+01**	**3.76E+02**	**6.08E+00**	**3.82E+02**	**4.56E+00**	**8.03E+00**	**1.26E+01**		
	Total IA Result	**kg N eq**											**4.13E+02**
Ozone Depletion Potential	Foundations	kg CFC-11 eq				7.06E-09	7.66E-10	**7.82E-09**	0.00E+00	8.04E-10	**8.04E-10**	**8.63E-09**	
	Walls	kg CFC-11 eq				1.89E-03	4.99E-07	**1.90E-03**	6.00E-10	6.59E-07	**6.60E-07**	**1.90E-03**	
	Floors	kg CFC-11 eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Columns & Beams	kg CFC-11 eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Roof	kg CFC-11 eq				1.37E-05	8.06E-08	**1.38E-05**	0.00E+00	1.56E-07	**1.56E-07**	**1.39E-05**	
	Process Total	**kg CFC-11 eq**	**1.78E-05**	**5.48E-07**	**1.84E-05**	**1.91E-03**	**5.80E-07**	**1.91E-03**	**6.00E-10**	**8.16E-07**	**8.16E-07**		
	Total IA Result	**kg CFC-11 eq**											**1.93E-03**
Smog Potential	Foundations	kg NOx eq				1.28E+00	1.78E-01	**1.46E+00**	0.00E+00	4.53E-01	**4.53E-01**	**1.92E+00**	
	Walls	kg NOx eq				4.21E+03	1.16E+02	**4.32E+03**	1.13E+02	1.47E+02	**2.59E+02**	**4.58E+03**	
	Floors	kg NOx eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Columns & Beams	kg NOx eq				0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**0.00E+00**	
	Roof	kg NOx eq				2.58E+03	1.73E+01	**2.60E+03**	0.00E+00	2.71E+01	**2.71E+01**	**2.62E+03**	
	Process Total	**kg NOx eq**	**2.82E+02**	**9.42E+01**	**3.76E+02**	**6.79E+03**	**1.33E+02**	**6.92E+03**	**1.13E+02**	**1.74E+02**	**2.87E+02**		
	Total IA Result	**kg NOx eq**											**7.58E+03**

Table 26 Building New Scenario impact assessment results by assembly group and life cycle stage.

Impact Category	Assembly Group	Category Indicator	Building New Scenario Life Cycle Stages										
			Full Demolition Existing Building			Manufacturing New Materials			Full Construction New Building			Assembly Group Total	Total Impact Assessment Result
			Material	Transportation	Total	Material	Transportation	Total	Material	Transportation	Total		
Fossil Fuel Consumption	Foundations	MJ				1.20E+06	7.75E+04	**1.28E+06**	7.82E+04	1.16E+05	**1.94E+05**	**1.47E+06**	
	Walls	MJ				1.39E+07	4.11E+05	**1.43E+07**	4.65E+05	1.01E+06	**1.47E+06**	**1.58E+07**	
	Floors	MJ				3.75E+06	1.94E+05	**3.94E+06**	5.11E+05	2.72E+05	**7.83E+05**	**4.72E+06**	
	Cloumns & Beams	MJ				5.34E+06	1.42E+05	**5.48E+06**	0.00E+00	1.38E+05	**1.38E+05**	**5.62E+06**	
	Roof	MJ				1.22E+07	6.98E+04	**1.23E+07**	8.24E+04	1.10E+05	**1.93E+05**	**1.25E+07**	
	Process Total	**MJ**	**7.85E+06**	**6.12E+05**	**8.46E+06**	**3.64E+07**	**8.94E+05**	**3.73E+07**	**1.14E+06**	**1.64E+06**	**2.78E+06**		
	Total IA Result	**MJ**											**4.85E+07**
Weighted Resource Use	Foundations	kg				1.87E+06	2.42E+03	**1.87E+06**	1.81E+03	2.73E+03	**4.54E+03**	**1.87E+06**	
	Walls	kg				7.88E+06	1.28E+04	**7.89E+06**	1.08E+04	2.37E+04	**3.45E+04**	**7.92E+06**	
	Floors	kg				4.41E+06	5.98E+03	**4.41E+06**	1.18E+04	6.41E+03	**1.83E+04**	**4.43E+06**	
	Cloumns & Beams	kg				2.31E+06	3.99E+03	**2.31E+06**	0.00E+00	3.25E+03	**3.25E+03**	**2.32E+06**	
	Roof	kg				1.29E+06	2.14E+03	**1.29E+06**	1.91E+03	2.60E+03	**4.51E+03**	**1.30E+06**	
	Process Total	**kg**	**1.85E+05**	**1.44E+04**	**1.99E+05**	**1.78E+07**	**2.74E+04**	**1.78E+07**	**2.63E+04**	**3.87E+04**	**6.51E+04**		
	Total IA Result	**kg**											**1.80E+07**
Global Warming Potential	Foundations	kg CO2 eq				2.00E+05	5.83E+03	**2.06E+05**	5.26E+03	8.60E+03	**1.39E+04**	**2.20E+05**	
	Walls	kg CO2 eq				1.44E+06	3.17E+04	**1.47E+06**	3.29E+04	7.25E+04	**1.05E+05**	**1.57E+06**	
	Floors	kg CO2 eq				5.07E+05	1.46E+04	**5.21E+05**	3.52E+04	2.00E+04	**5.52E+04**	**5.76E+05**	
	Cloumns & Beams	kg CO2 eq				3.58E+05	1.07E+04	**3.69E+05**	0.00E+00	1.03E+04	**1.03E+04**	**3.79E+05**	
	Roof	kg CO2 eq				4.59E+05	5.20E+03	**4.65E+05**	5.49E+03	8.20E+03	**1.37E+04**	**4.78E+05**	
	Process Total	**kg CO2 eq**	**5.12E+05**	**4.58E+04**	**5.58E+05**	**2.96E+06**	**6.80E+04**	**3.03E+06**	**7.89E+04**	**1.20E+05**	**1.98E+05**		
	Total IA Result	**kg CO2 eq**											**3.78E+06**
Acidification Potential	Foundations	moles of H+ eq				7.99E+04	2.48E+03	**8.23E+04**	2.69E+03	2.73E+03	**5.43E+03**	**8.78E+04**	
	Walls	moles of H+ eq				7.14E+05	1.30E+04	**7.27E+05**	1.72E+04	2.36E+04	**4.09E+04**	**7.68E+05**	
	Floors	moles of H+ eq				2.03E+05	6.14E+03	**2.10E+05**	1.90E+04	6.41E+03	**2.54E+04**	**2.35E+05**	
	Cloumns & Beams	moles of H+ eq				1.49E+05	4.08E+03	**1.53E+05**	0.00E+00	3.25E+03	**3.25E+03**	**1.56E+05**	
	Roof	moles of H+ eq				2.34E+05	2.11E+03	**2.36E+05**	3.09E+03	2.60E+03	**5.70E+03**	**2.42E+05**	
	Process Total	**moles of H+ eq**	**2.84E+04**	**1.44E+04**	**4.28E+04**	**1.38E+06**	**2.78E+04**	**1.41E+06**	**4.20E+04**	**3.86E+04**	**8.06E+04**		
	Total IA Result	**moles of H+ eq**											**1.53E+06**
Human Health Respiratory Effects Potential	Foundations	kg PM2.5 eq				5.47E+02	3.02E+00	**5.50E+02**	2.66E+00	3.29E+00	**5.95E+00**	**5.56E+02**	
	Walls	kg PM2.5 eq				5.18E+03	1.58E+01	**5.20E+03**	1.95E+01	2.84E+01	**4.80E+01**	**5.24E+03**	
	Floors	kg PM2.5 eq				1.36E+03	7.46E+00	**1.36E+03**	2.13E+01	7.71E+00	**2.90E+01**	**1.39E+03**	
	Cloumns & Beams	kg PM2.5 eq				8.85E+02	4.94E+00	**8.90E+02**	0.00E+00	3.91E+00	**3.91E+00**	**8.94E+02**	
	Roof	kg PM2.5 eq				1.22E+03	2.56E+00	**1.23E+03**	3.50E+00	3.13E+00	**6.63E+00**	**1.23E+03**	
	Process Total	**kg PM2.5 eq**	**2.70E+01**	**1.74E+01**	**4.44E+01**	**9.19E+03**	**3.38E+01**	**9.22E+03**	**4.70E+01**	**4.65E+01**	**9.35E+01**		
	Total IA Result	**kg PM2.5 eq**											**9.36E+03**
Eutrophication Potential	Foundations	kg N eq				5.41E+01	2.62E+00	**5.67E+01**	2.35E+00	2.83E+00	**5.18E+00**	**6.19E+01**	
	Walls	kg N eq				6.72E+02	1.37E+01	**6.85E+02**	1.69E+01	2.45E+01	**4.14E+01**	**7.27E+02**	
	Floors	kg N eq				2.07E+02	6.47E+00	**2.13E+02**	1.88E+01	6.65E+00	**2.55E+01**	**2.39E+02**	
	Cloumns & Beams	kg N eq				4.20E+02	4.27E+00	**4.24E+02**	0.00E+00	3.37E+00	**3.37E+00**	**4.28E+02**	
	Roof	kg N eq				1.14E+02	2.22E+00	**1.16E+02**	3.09E+00	2.70E+00	**5.78E+00**	**1.22E+02**	
	Process Total	**kg N eq**	**1.95E+01**	**1.36E+01**	**3.31E+01**	**1.47E+03**	**2.93E+01**	**1.50E+03**	**4.11E+01**	**4.01E+01**	**8.12E+01**		
	Total IA Result	**kg N eq**											**1.61E+03**
Ozone Depletion Potential	Foundations	kg CFC-11 eq				4.01E-04	2.45E-07	**4.01E-04**	0.00E+00	3.52E-07	**3.52E-07**	**4.02E-04**	
	Walls	kg CFC-11 eq				2.31E-03	1.33E-06	**2.31E-03**	5.85E-10	2.97E-06	**2.97E-06**	**2.31E-03**	
	Floors	kg CFC-11 eq				9.48E-04	6.14E-07	**9.49E-04**	0.00E+00	8.19E-07	**8.19E-07**	**9.49E-04**	
	Cloumns & Beams	kg CFC-11 eq				4.20E-04	4.44E-07	**4.20E-04**	0.00E+00	4.23E-07	**4.23E-07**	**4.21E-04**	
	Roof	kg CFC-11 eq				2.15E-04	2.18E-07	**2.15E-04**	0.00E+00	3.36E-07	**3.36E-07**	**2.16E-04**	
	Process Total	**kg CFC-11 eq**	**2.31E-05**	**1.87E-06**	**2.49E-05**	**4.29E-03**	**2.85E-06**	**4.29E-03**	**5.85E-10**	**4.90E-06**	**4.90E-06**		
	Total IA Result	**kg CFC-11 eq**											**4.32E-03**
Smog Potential	Foundations	kg NOx eq				1.06E+03	5.74E+01	**1.12E+03**	6.18E+01	6.10E+01	**1.23E+02**	**1.24E+03**	
	Walls	kg NOx eq				7.14E+03	3.00E+02	**7.44E+03**	4.30E+02	5.29E+02	**9.60E+02**	**8.40E+03**	
	Floors	kg NOx eq				2.59E+03	1.42E+02	**2.73E+03**	8.17E+02	1.43E+02	**9.60E+02**	**3.69E+03**	
	Cloumns & Beams	kg NOx eq				1.44E+03	9.32E+01	**1.54E+03**	0.00E+00	7.26E+01	**7.26E+01**	**1.61E+03**	
	Roof	kg NOx eq				3.14E+03	4.86E+01	**3.18E+03**	7.51E+01	5.81E+01	**1.33E+02**	**3.32E+03**	
	Process Total	**kg NOx eq**	**3.65E+02**	**3.22E+02**	**6.87E+02**	**1.54E+04**	**6.41E+02**	**1.60E+04**	**1.38E+03**	**8.64E+02**	**2.25E+03**		
	Total IA Result	**kg NOx eq**											**1.89E+04**

Appendix F Resource Use and Environmental Impact Cost Savings

The following are details of the methods, data sources and assumptions used to determine the costs savings associated with UBC Project Services decision to pursue the Renovation scenario rather than the Building New scenario.

In the BioSciences LCA study, environmental savings were established for the Renovation scenario measured against the Building New scenario. Among these savings are fuel resources like crude oil, natural gas and water as well as environmental impacts like global warming potential, acidification, eutrophication, respiratory effects etc. The savings of these resources and impacts may also be equated to economic cost in terms of the cost of the fuel savings, which are built into the existing price difference of the two scenarios, and environmental impact savings, that are unrealized because of a lack of legislation to do so but may similarly be calculated.

Fuel and Water Cost Savings

The resource savings in the BioSciences LCA study were established based on the raw material consumption ("Raw" in Table 1) at the point of extraction (coal mining, oil and natural gas drilling, water supply). To calculate the cost of consuming these resources in the manufacture and delivery of building materials, the conversion efficiency loss and production energy use were first subtracted to determine the amount of fuel and water that were consumed ("At User" in Table 1). Next, the cost of the fuels and water were estimated based on current market prices in the Vancouver metro region. The results of this costing analysis are provided in Table 1.

Table 1: Fuel and Water Cost Savings

Resource	Unit	Raw	At User[15]	Cost Per Unit	Total Cost
Coal	ton	16	15.2	$101.54[16]	$1,545
Natural Gas	m^3	280,000	255,725	$0.39[17]	$98,830
Crude Oil (assumed as Gasoline)	liters	120,000	119,683	$1.27[18]	$152,400
Water	m^3	4,000	4,000	$0.45[19]	$1,794
Total					**$254,569**

Based on the fuel prices and consumption estimates, the renovation scenario from the LCA was found to save more than $254,000 in fuel and water costs alone. It should be noted that these costs are already incorporated into the different cost of the materials used in the two scenarios – and are based strictly on current BC prices that do not necessarily reflect the price of fuel and water in the region in which the products originated.

BC Carbon Tax Savings

The fuel cost savings may also be considered in terms of the carbon tax currently in effect in British Columbia. The carbon tax accounts for a higher percentage of the total fuel cost for fuels that have a lower cost to CO_2 emissions ratio, and lowest for fuels that have a higher cost to CO_2 ratio. These carbon tax costs are shown in Table 2.

[15] http://www.nrel.gov/lci/
[16] Pre C tax cost from http://www.nrcan.gc.ca/eneene/sources/coacha-eng.php - Total cost calculated based on this rate and C tax in Table 2
[17] Calculated based on $9.13 per GJ rate from http://www.fortisbc.com/NaturalGas/Homes/Rates/Pages/Lower-Mainland.aspx and the higher heating value of natural gas 38.66 mj/m3 from http:www.nrel.gov/lci/
[18] http://www.vancouvergasprices.com/
[19] http://www.cityofvancouver.us/MunicipalCode.asp?menuid=10462&submenuID=10478&title=title_14&chapter=04&VMC=210.html

Table 2: BC Carbon Tax Savings

Resource	Unit	Tax per Unit	Carbon Cost	% of Fuel Cost
Coal	ton	$41.54	$632	41%
Natural Gas	m^3	$0.038	$9,718	9.8%
Crude Oil (assumed as Gasoline)	liters	$0.0445	$5,326	3.5%
Total			**$15,676**	**6.2%**

The natural gas reduction results in the greatest carbon tax savings, while the carbon tax on coal accounts for the greatest percent increase in fuel cost. The savings in carbon tax alone account for more than $15,000, or roughly 6% of the total fuel cost calculated in Table 1. These costs are only incorporated into the different cost of the materials used in the two scenarios if those construction products originated in BC and were produced in facilities that paid the BC carbon tax – otherwise they are unrealized costs similar to the environmental impact cost savings in the following section.

Environmental Impact Cost Savings

In addition to the fuel-related cost savings that are realized in the different material prices of the two scenarios, several of the environmental impacts also carry economic burden that may not be built into the price structure of the material life cycles that cause them.

The most familiar of these is the previously discussed cost of carbon emissions, partially accounted for by the BC tax scheme for fuels. The carbon tax-based costing is only partial in that it is not present in the cost of materials produced outside of BC, and because it ignores non-fuel emissions like those from the calcination of calcium carbonate in cement manufacturing.

The economic costs of the environmental impacts are calculated based on models specific to each that were developed by Dr. Jeffrey Morris of the University of California at Berkeley and were updated and expanded for this project. This modeling, shown in Table 3, relates the impacts to market prices for impact abatement and loss of productivity in the case of health effects[20].

Global Warming: For global warming, we used the BC price for carbon ($25 per ton CO_2 eq.) that was the basis of the carbon taxes discussed previously and is also used to price provincial government-backed carbon offsets[21]

HH Respiratory Effects: The cost of the respiratory effects was developed by first estimating the respiratory effects on human health, 0.433 DALY/ton $PM_{2.5}$ where DALY is a unit of human health degradation called Disability Adjusted Life Years[22]. We then equated the estimate of DALYs to the average employment wage in BC in 2011 - $43,160[23].

[20] Morris, Jeffrey, and Jennifer Bagby (2008). Measuring Environmental Value for Natural Lawn and Garden Care Practices. *International Journal of Life Cycle Assessment*, 13(3) 226-234

[21] http://www.pacificcarbontrust.com/BuyOffsets/tabid/64/Default.aspx

[22] Based on 0.26 DALY/ton PM10 from http://www.lcia-recipe.net/ and characterization of PM10 to PM2.5 in TRACI of 0.6

[23] http://www.bcstats.gov.bc.ca/pubs/eet/eetdata.pdf#page=3

Smog and Acidification: The acidification and smog costs are based on the US EPA's spot market prices for emissions permits, \$2.00 per ton SO_2[24] (equivalent to 3.9 cents per 1000 moles H+) and \$150 per ton NOx[25].

Eutrophication: The price of eutrophication was determined based on US EPA estimates to remove nitrogen from freshwater, \$4.41 per ton N[26].

Table 3: Environmental Impact Cost Savings

Impact Assessment Category	Unit	Savings	Cost per unit	$ Savings
HH Respiratory Effects	ton $PM_{2.5}$ eq.	4.1	\$18,702	\$76,681
Global Warming	ton CO_2 eq.	2,400	\$25	\$60,000
Smog	ton NOx eq.	11	\$150	\$1,650
Acidification	10^3 moles H+ eq.	860	\$0.039	\$33.86
Eutrophication	ton N eq.	1.2	\$4.41	\$5.29
Total				**\$138,370**

The results indicate that the greatest environmental cost savings is in the category human health respiratory effects with a savings of \$76,681 and that the total environmental cost savings exceeds \$138,370. One point to notice is that the savings in terms of human health effects caused by respiratory irritants is equal to 1.77 times the cost/DALY – which means that the choice of the Renovation over Building New scenario for the BioSciences building is cumulatively equivalent to keeping a person from being disabled for a year and 9 months.

Concluding Remarks

The cost savings noted in this appendix are significant in their overall scale, exceeding \$254,000 in fuel and water costs and \$138,000 in environmental and human health costs. The savings to human health effects is perhaps the most compelling though. While it is always difficult to assign a value to environmental impacts and especially human health effects, the cost of cleanup and loss of productivity serve as useful proxies but inevitably underestimate the total cost of these impacts. It must be noted that the Renovation scenario prevents impacts that are at a minimum the costs described in this appendix.

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24 http://new.evomarkets.com/index.php?page=Emissions_Markets

25 Cost for acidification given in terms of tons SO_2 eq. which was converted to the corresponding moles of H+ eq. by using the characterization factor in TRACI for SO_2 of 50.79 H+ eq.

26 US Environmental Protection Agency, Office of Research and Development (2002b): Economic Analysis of the Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations. EPA-812-R-03-002, December 2002, Washington, DC